Exhibit 4

US010715235B2

(12) **United States Patent**
Da Silva et al.

(10) **Patent No.: US 10,715,235 B2**
(45) **Date of Patent: Jul. 14, 2020**

(54) **DIRECTED WIRELESS COMMUNICATION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/495,539**

(22) Filed: **Apr. 24, 2017**

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US 2017/0230094 A1 Aug. 10, 2017

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(Continued)

(51) **Int. Cl.**
H04B 7/06 (2006.01)
H04B 7/04 (2017.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04B 7/0617*** (2013.01); ***H04B 7/04*** (2013.01); ***H04B 7/0621*** (2013.01);
(Continued)

(58) **Field of Classification Search**
None
See application file for complete search history.

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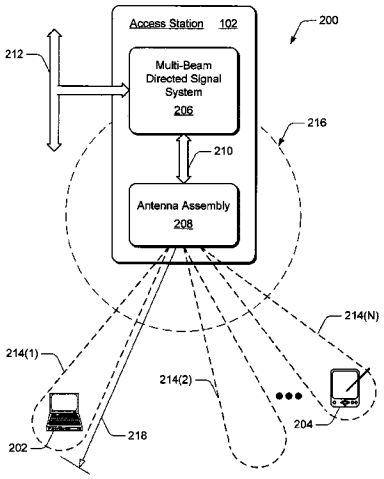
Primary Examiner — Shuwang Liu
Assistant Examiner — Gina M McKie
(74) *Attorney, Agent, or Firm* — Klein, O'Neill & Singh, LLP

(57) **ABSTRACT**

Disclosed herein are methods and apparatuses configured to direct wireless communication. In some embodiments, a network apparatus is configured to: receive a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously; determine first signal information for the first transmission; determine second signal information for the second transmission, wherein the second signal information is different than the first signal information; determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to construct one or
(Continued)



more beam-formed transmission signals; and generate the one or more beam-formed transmission signals based on the set of weighting values for transmission to the remote station.

19 Claims, 18 Drawing Sheets

Related U.S. Application Data

No. 13/855,410, filed on Apr. 2, 2013, now Pat. No. 9,462,589, which is a division of application No. 10/700,329, filed on Nov. 3, 2003, now Pat. No. 8,412,106.

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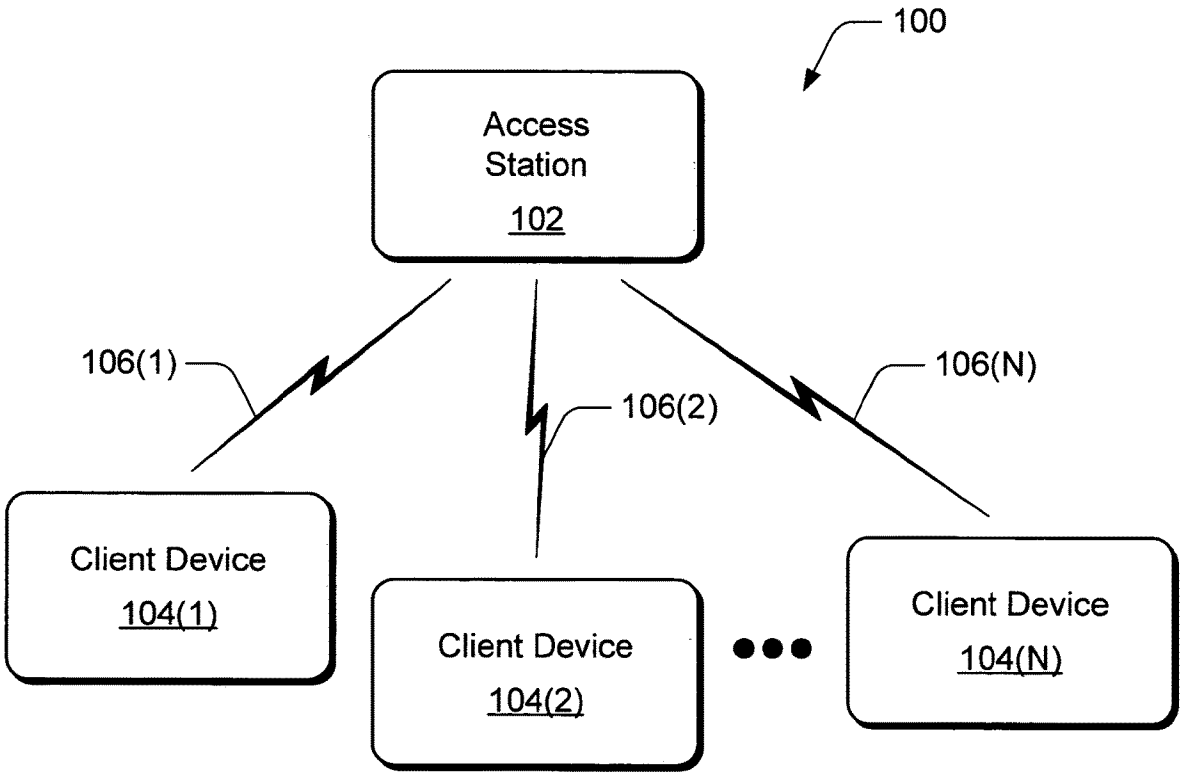
100
Access Station 102
106(1)
106(2)
106(N)
Client Device 104(1)
Client Device 104(2)
Client Device 104(N)

Fig. 1

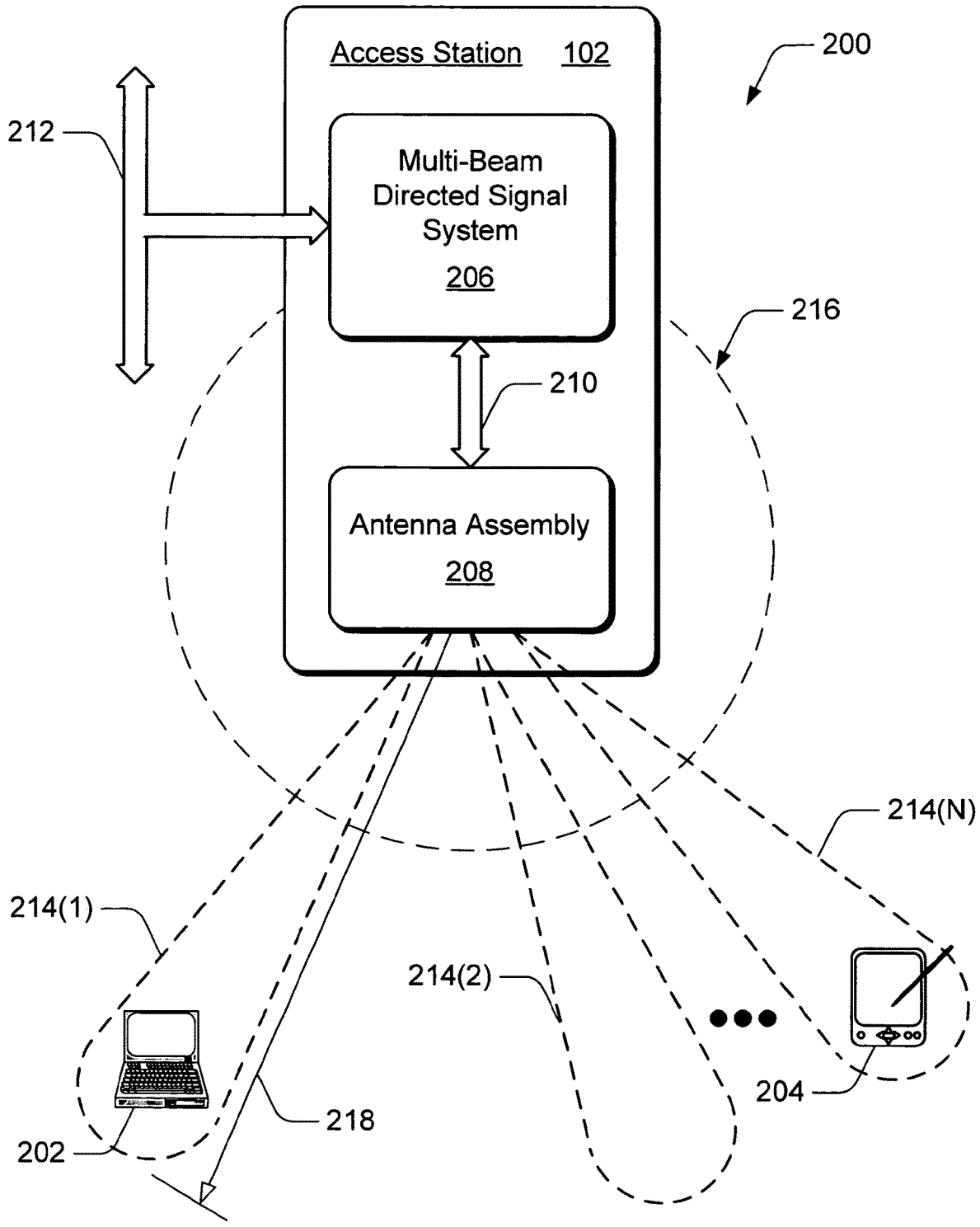
Access Station 102
200
212
Multi-Beam Directed Signal System
206
216
210
Antenna Assembly
208
214(N)
214(1)
214(2)
204
218
202

Fig. 2

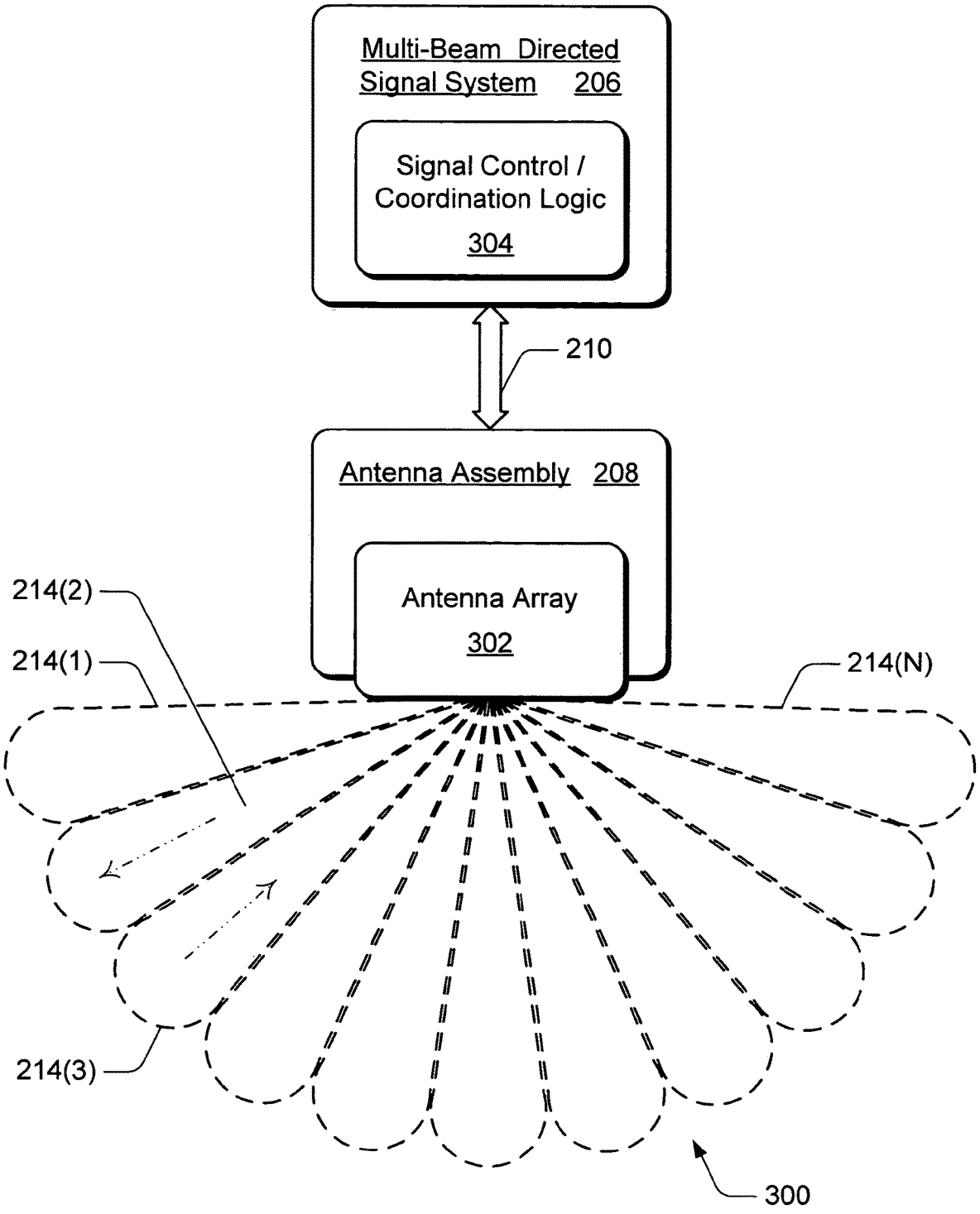
Multi-Beam Directed Signal System 206
Signal Control / Coordination Logic 304
210
Antenna Assembly 208
Antenna Array 302
214(2)
214(1)
214(N)
214(3)
300

Fig. 3

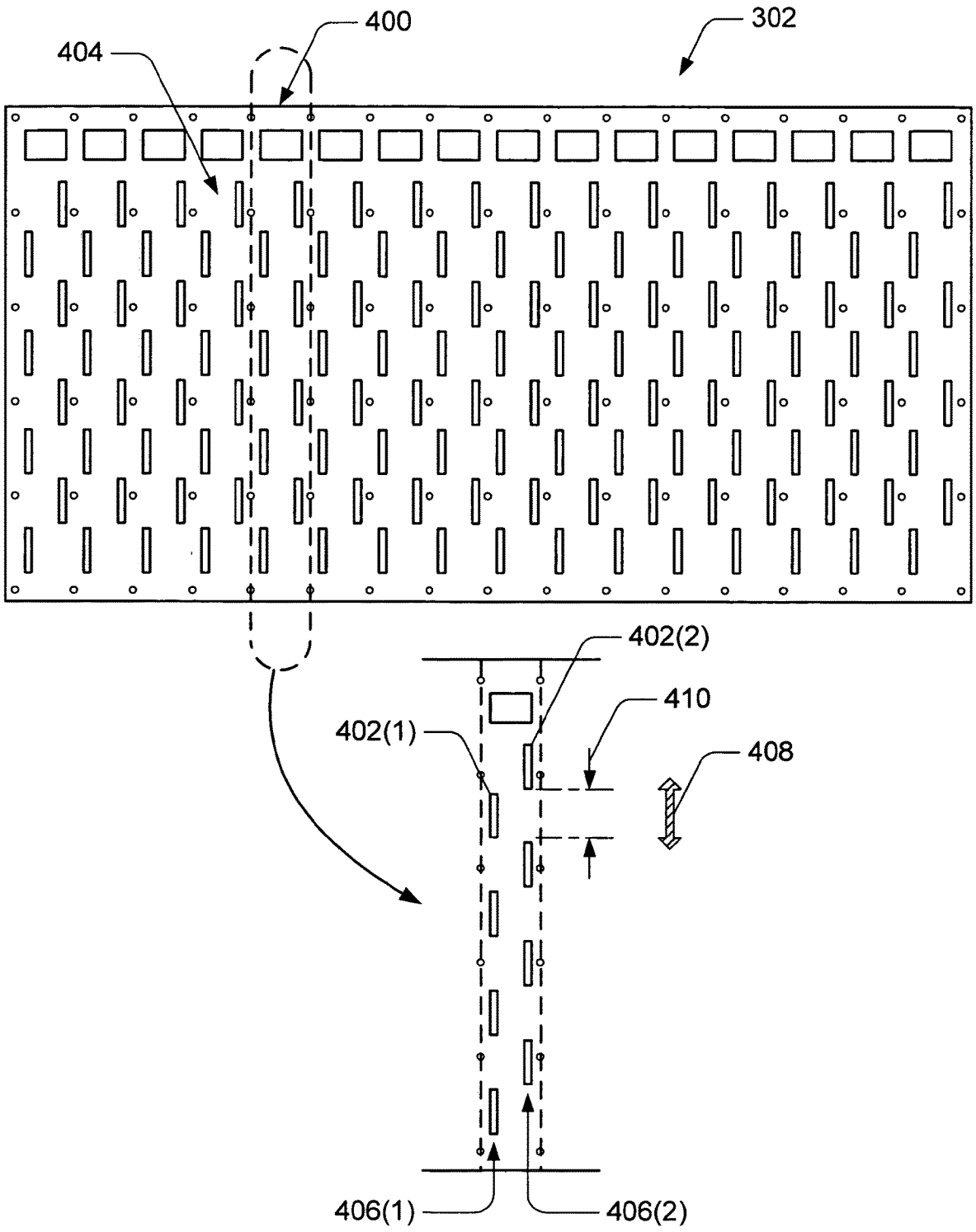

Fig. 4

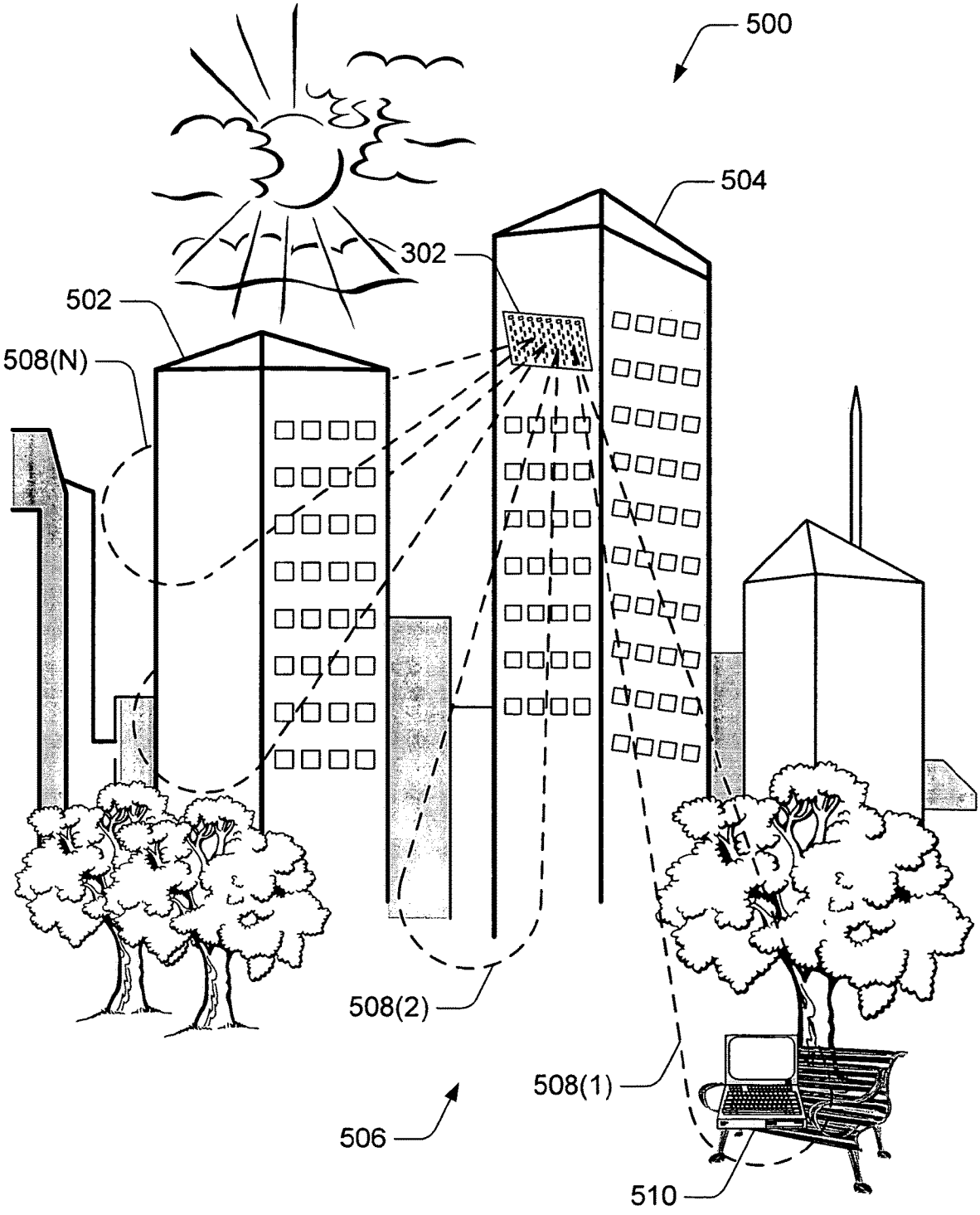

Fig. 5

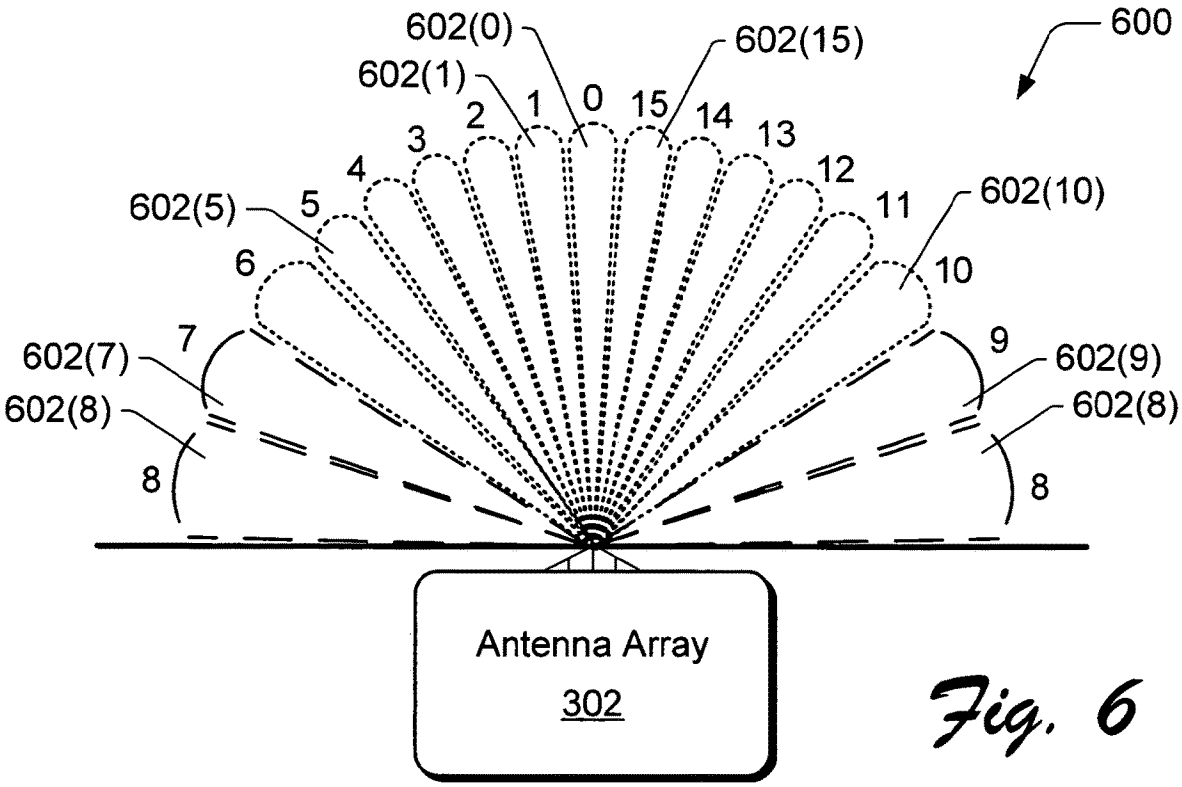
600
602(0)
602(1)
602(15)
602(5)
602(10)
602(7)
602(9)
602(8)
602(8)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Antenna Array
302

Fig. 6

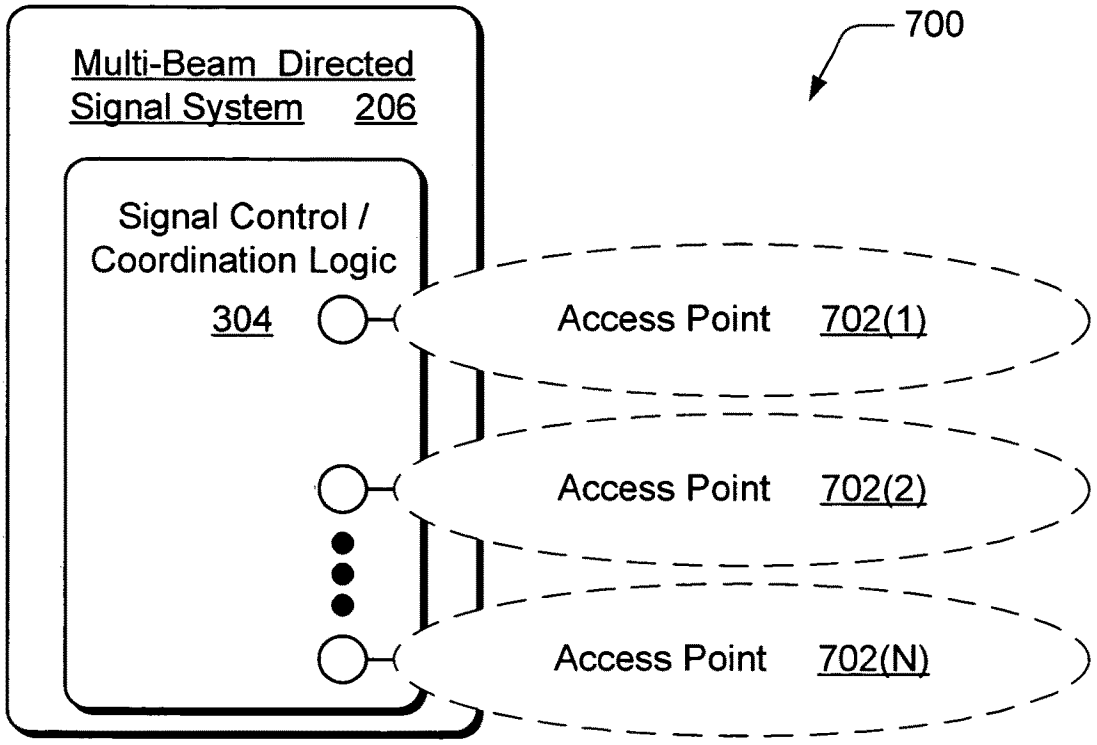
700
Multi-Beam Directed Signal System 206
Signal Control / Coordination Logic
304
Access Point 702(1)
Access Point 702(2)
Access Point 702(N)

Fig. 7

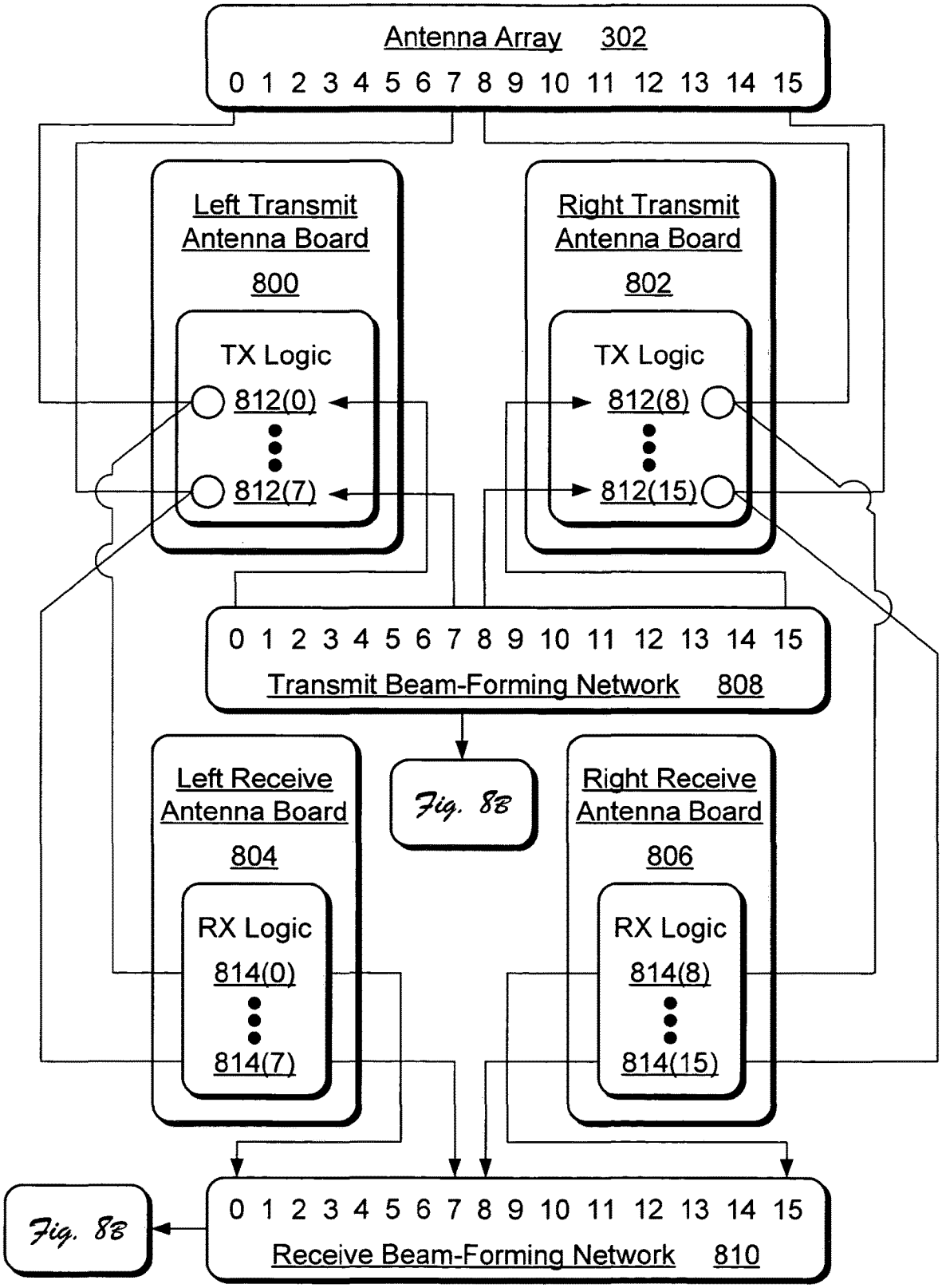
Antenna Array 302
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Left Transmit Antenna Board 800
TX Logic
812(0)
812(7)
Right Transmit Antenna Board 802
TX Logic
812(8)
812(15)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Transmit Beam-Forming Network 808
Fig. 8B
Left Receive Antenna Board 804
RX Logic
814(0)
814(7)
Right Receive Antenna Board 806
RX Logic
814(8)
814(15)
Fig. 8B
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Receive Beam-Forming Network 810

Fig. 8A

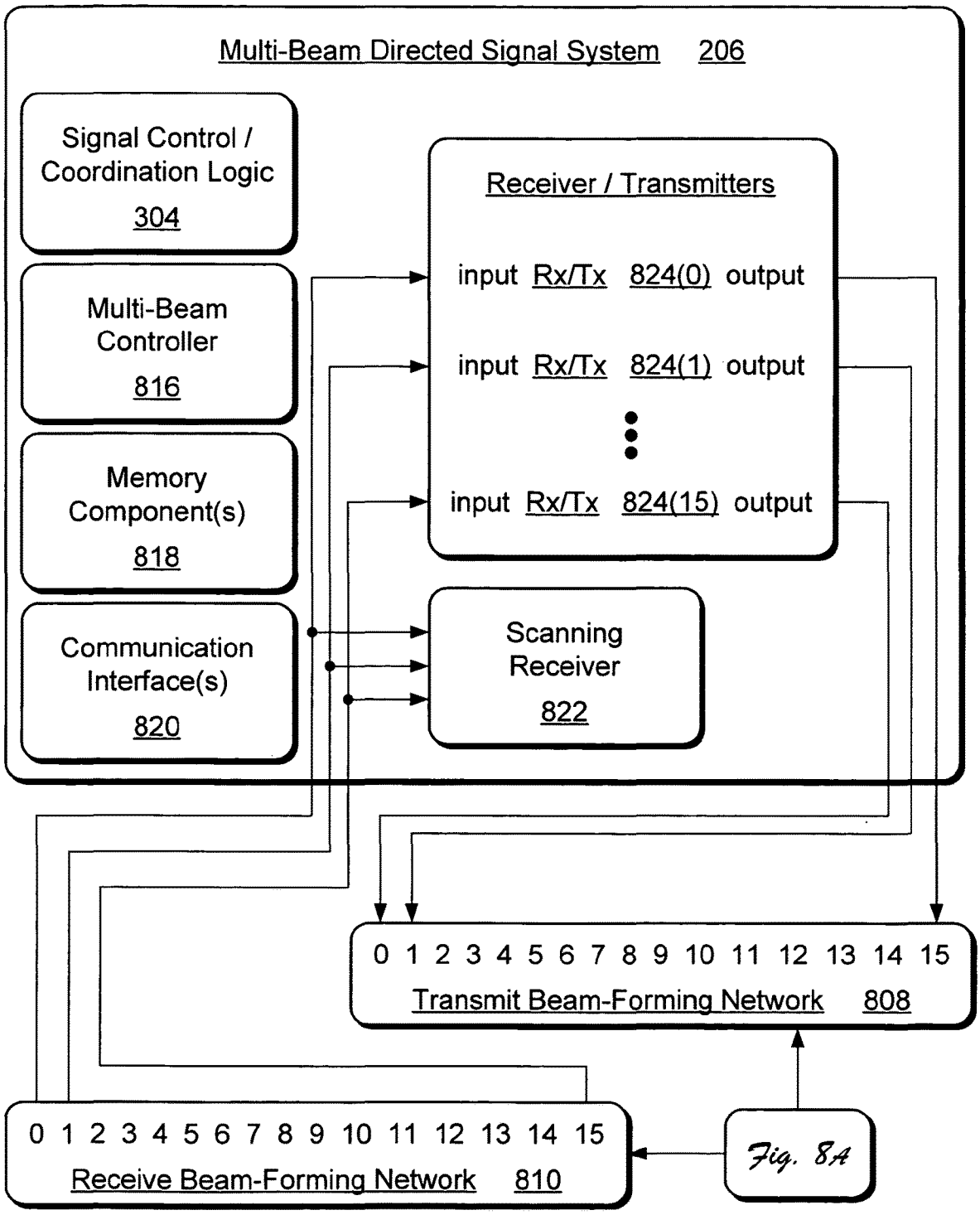
Multi-Beam Directed Signal System 206
Signal Control / Coordination Logic 304
Multi-Beam Controller 816
Memory Component(s) 818
Communication Interface(s) 820
Receiver / Transmitters
input Rx/Tx 824(0) output
input Rx/Tx 824(1) output
input Rx/Tx 824(15) output
Scanning Receiver 822
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Transmit Beam-Forming Network 808
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Receive Beam-Forming Network 810
Fig. 8A

Fig. 8B

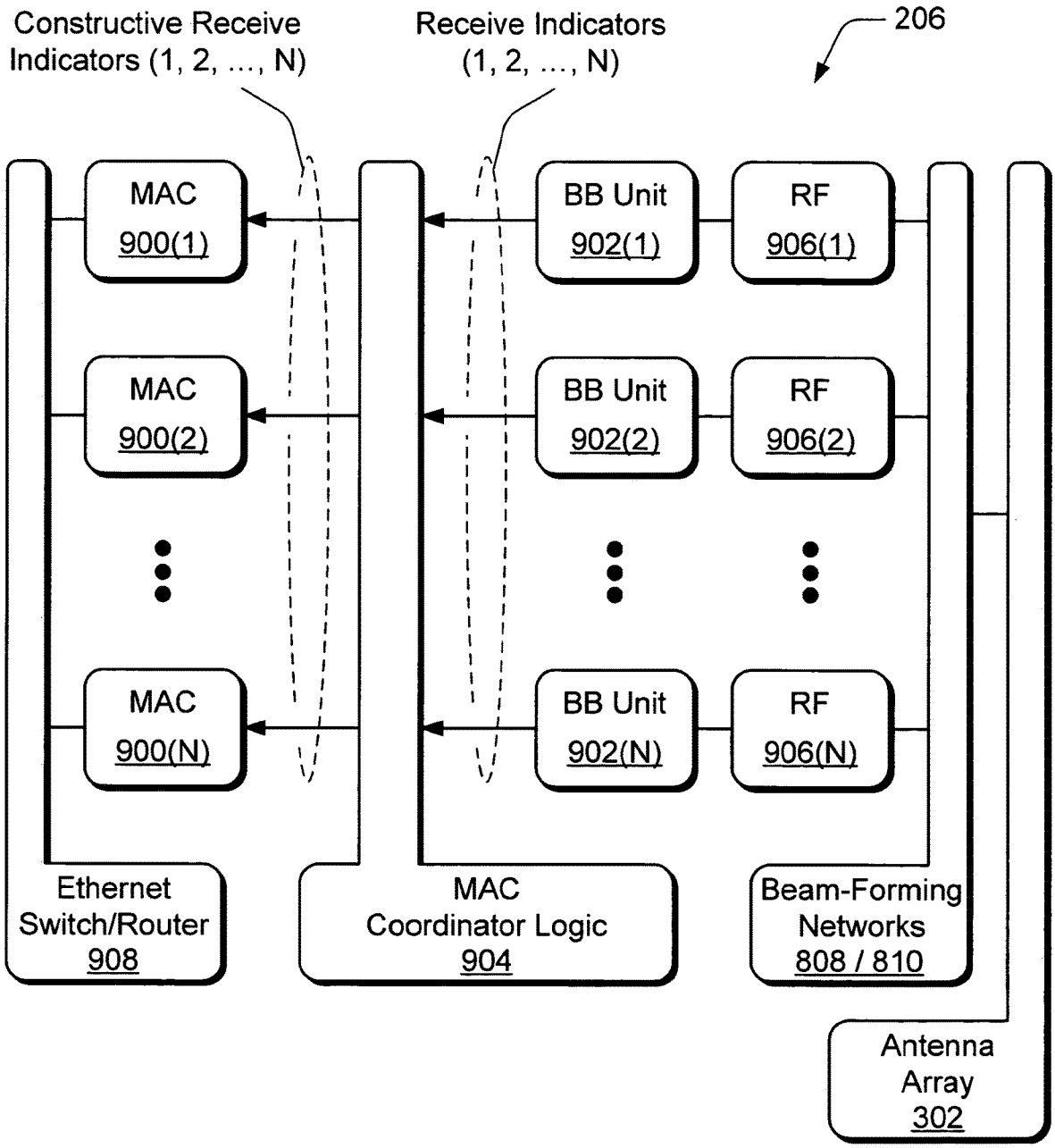
Constructive Receive Indicators (1, 2, ..., N)
Receive Indicators (1, 2, ..., N)
206
MAC 900(1)
MAC 900(2)
MAC 900(N)
BB Unit 902(1)
BB Unit 902(2)
BB Unit 902(N)
RF 906(1)
RF 906(2)
RF 906(N)
Ethernet Switch/Router 908
MAC Coordinator Logic 904
Beam-Forming Networks 808 / 810
Antenna Array 302

Fig. 9

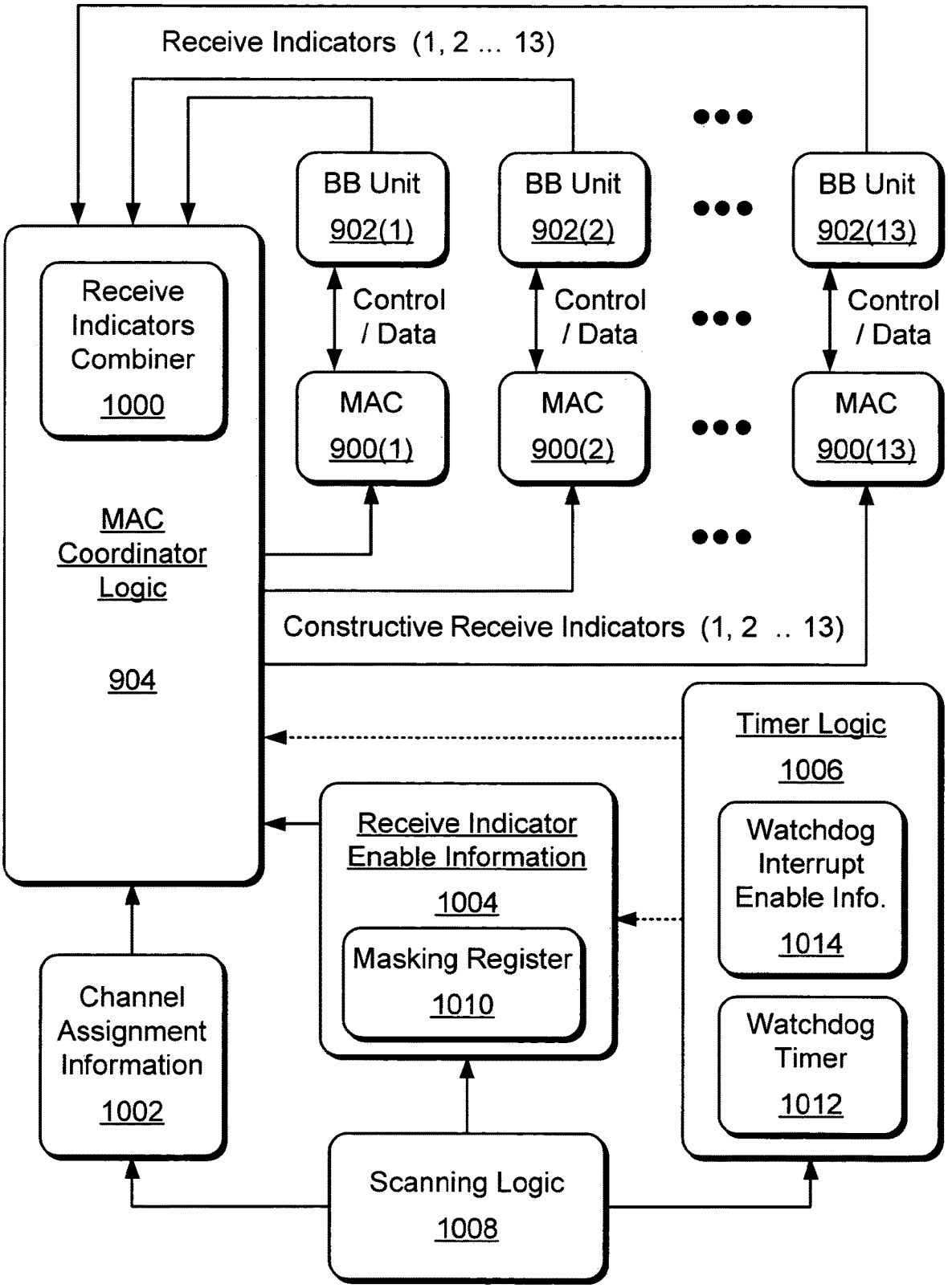
Receive Indicators (1, 2 ... 13)
BB Unit 902(1)
BB Unit 902(2)
BB Unit 902(13)
Receive Indicators Combiner 1000
Control / Data
Control / Data
Control / Data
MAC 900(1)
MAC 900(2)
MAC 900(13)
MAC Coordinator Logic
904
Constructive Receive Indicators (1, 2 .. 13)
Timer Logic 1006
Receive Indicator Enable Information 1004
Masking Register 1010
Watchdog Interrupt Enable Info. 1014
Watchdog Timer 1012
Channel Assignment Information 1002
Scanning Logic 1008

Fig. 10

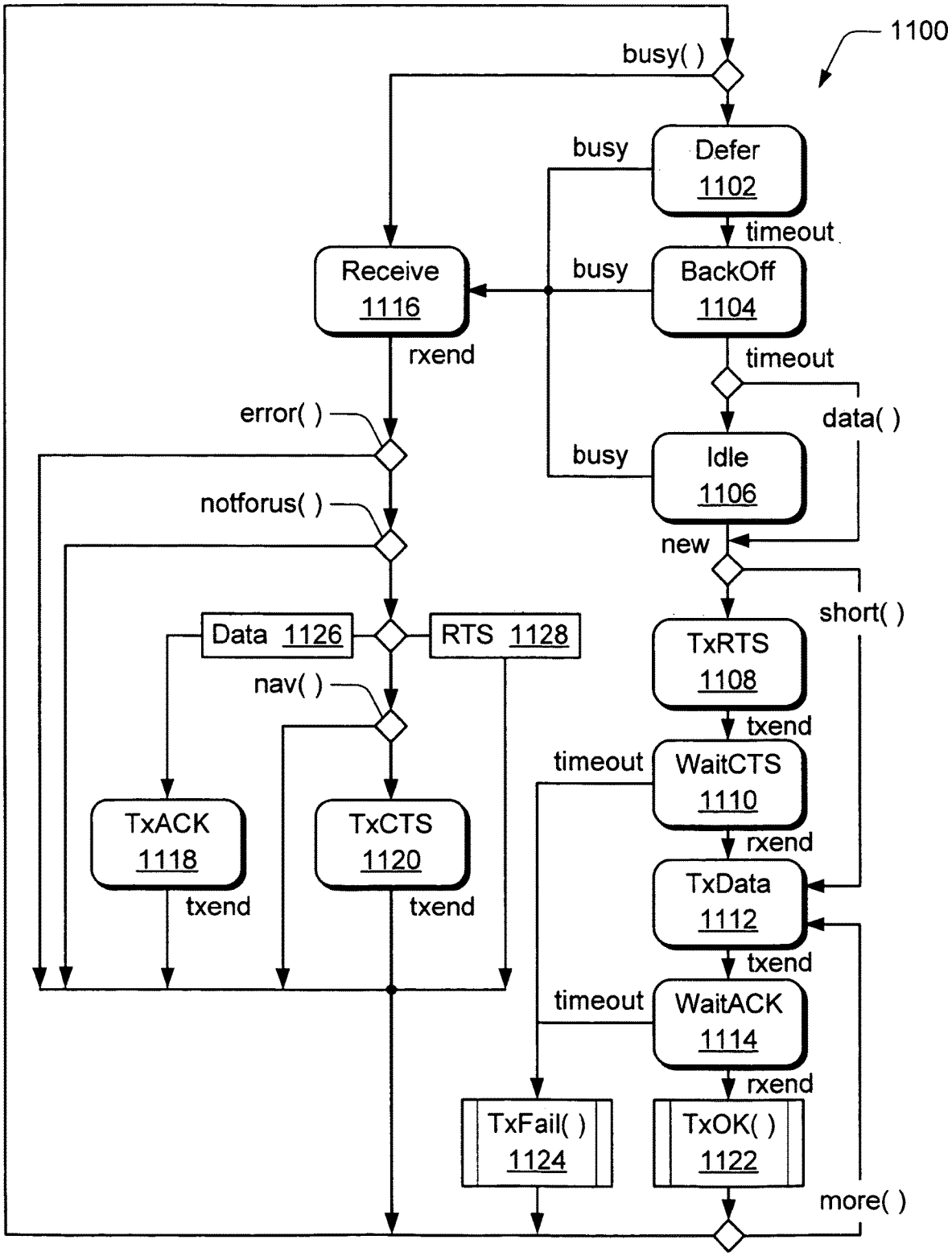
1100
busy( )
busy
Defer
1102
timeout
Receive
1116
busy
BackOff
1104
rxend
timeout
error( )
data( )
busy
Idle
1106
notforus( )
new
short( )
Data 1126
RTS 1128
TxRTS
1108
nav( )
txend
timeout
WaitCTS
1110
TxACK
1118
TxCTS
1120
rxend
TxData
1112
txend
txend
txend
timeout
WaitACK
1114
rxend
TxFail( )
1124
TxOK( )
1122
more( )

Fig. 11

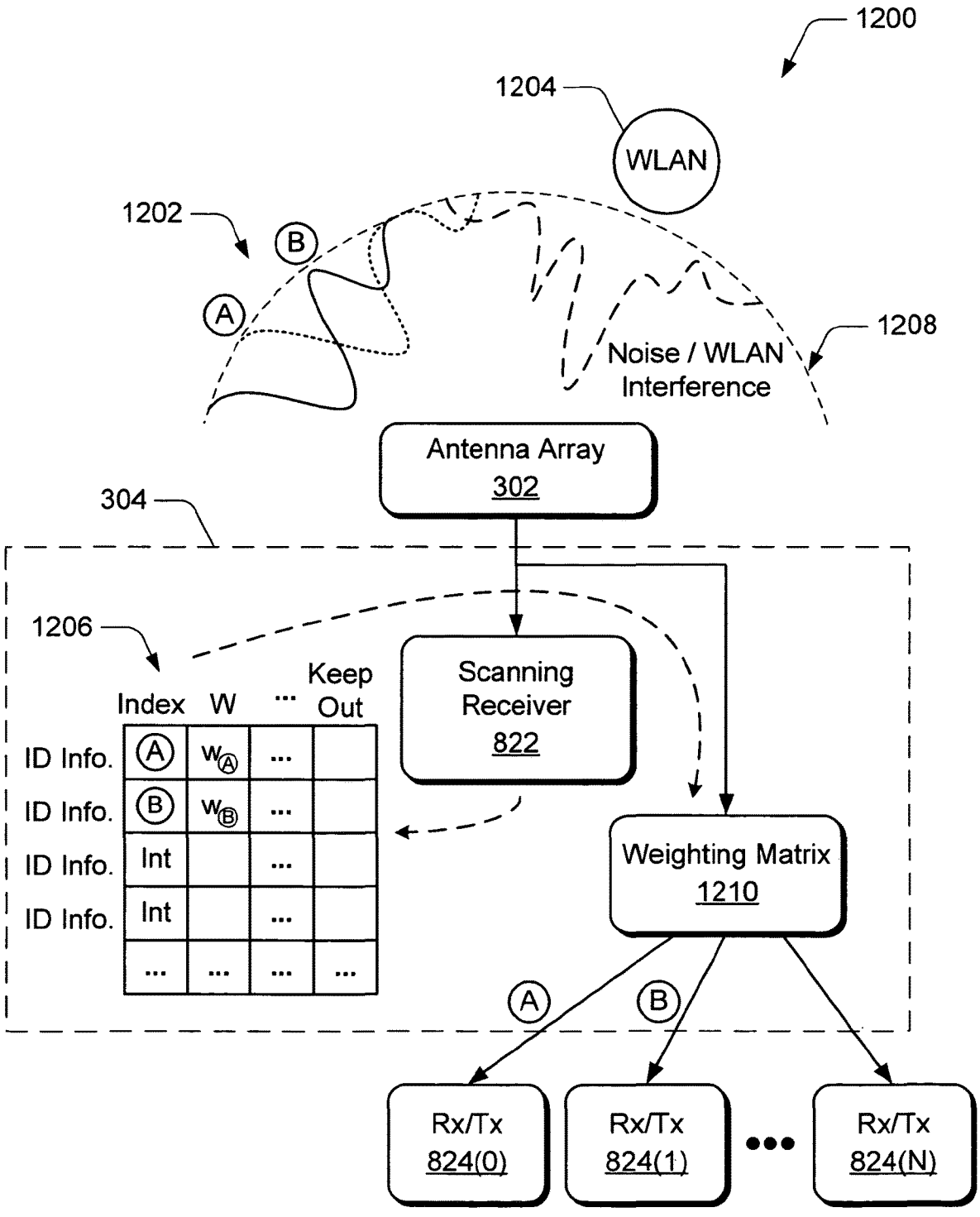
1200
1204
WLAN
1202
B
A
1208
Noise / WLAN Interference
Antenna Array 302
304
1206
Index W ... Keep Out
ID Info.
ID Info.
ID Info.
ID Info.
Int
Int
Scanning Receiver 822
Weighting Matrix 1210
A
B
Rx/Tx 824(0)
Rx/Tx 824(1)
Rx/Tx 824(N)

Fig. 12

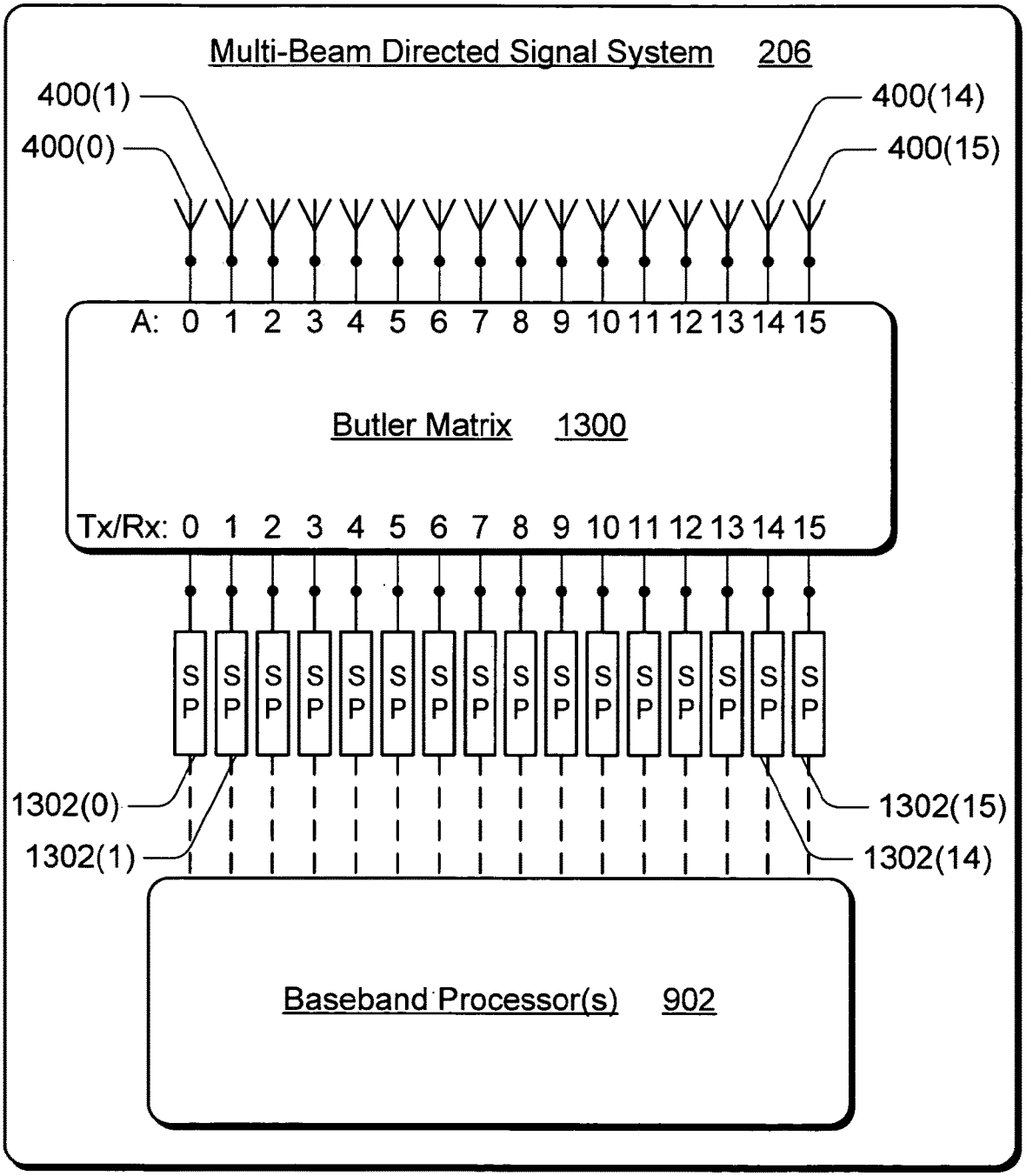
Multi-Beam Directed Signal System 206
400(1)
400(0)
400(14)
400(15)
A: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Butler Matrix 1300
Tx/Rx: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
SP
1302(0)
1302(1)
1302(15)
1302(14)
Baseband Processor(s) 902

Fig. 13

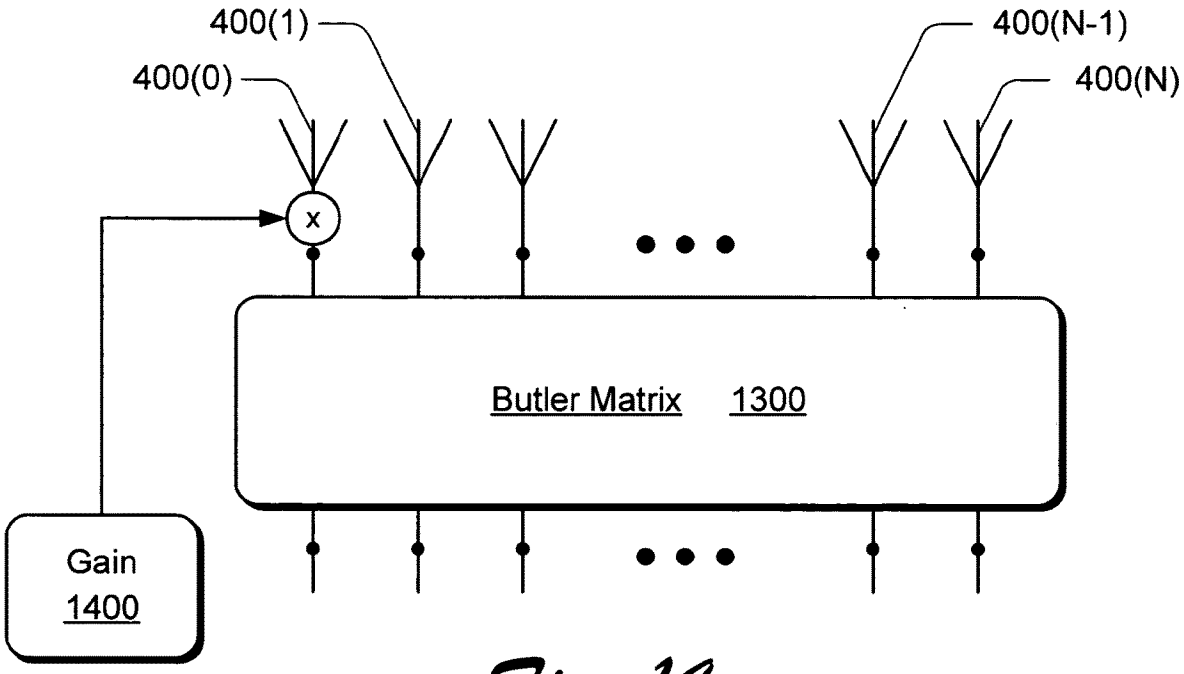
400(1)
400(0)
400(N-1)
400(N)
x
Butler Matrix 1300
Gain
1400

Fig. 14

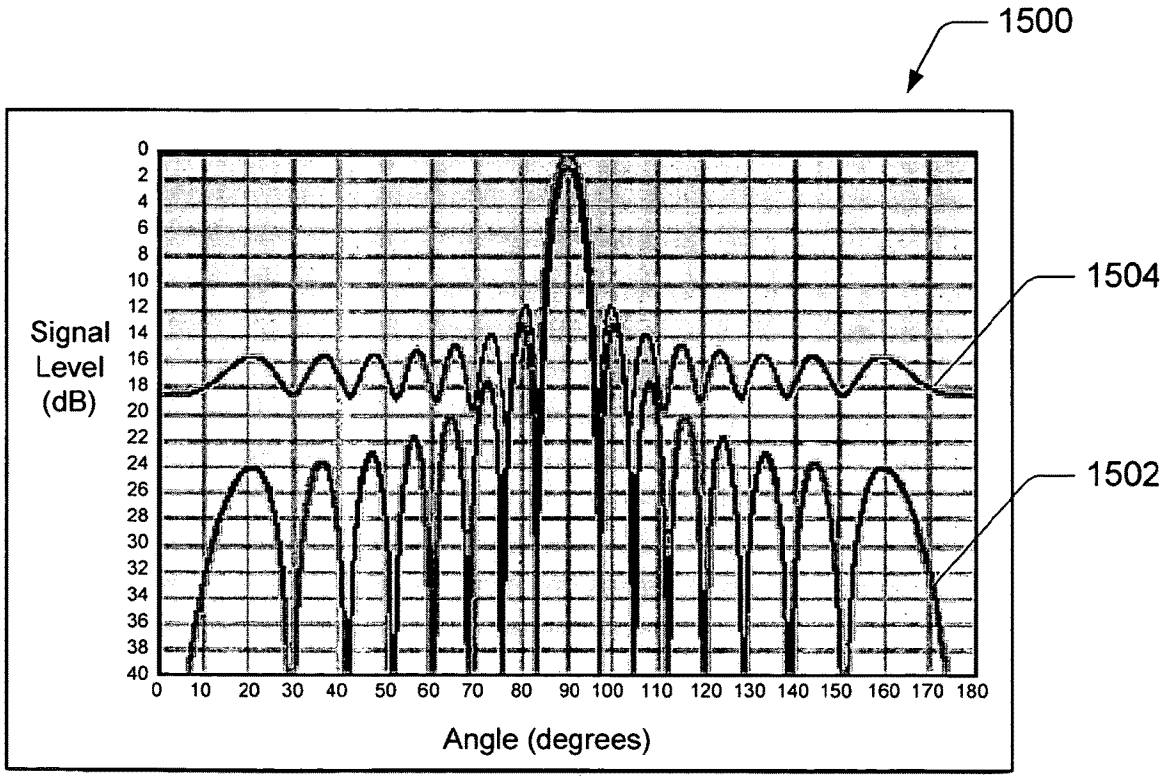
1500
1504
1502
Signal Level (dB)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
Angle (degrees)

Fig. 15

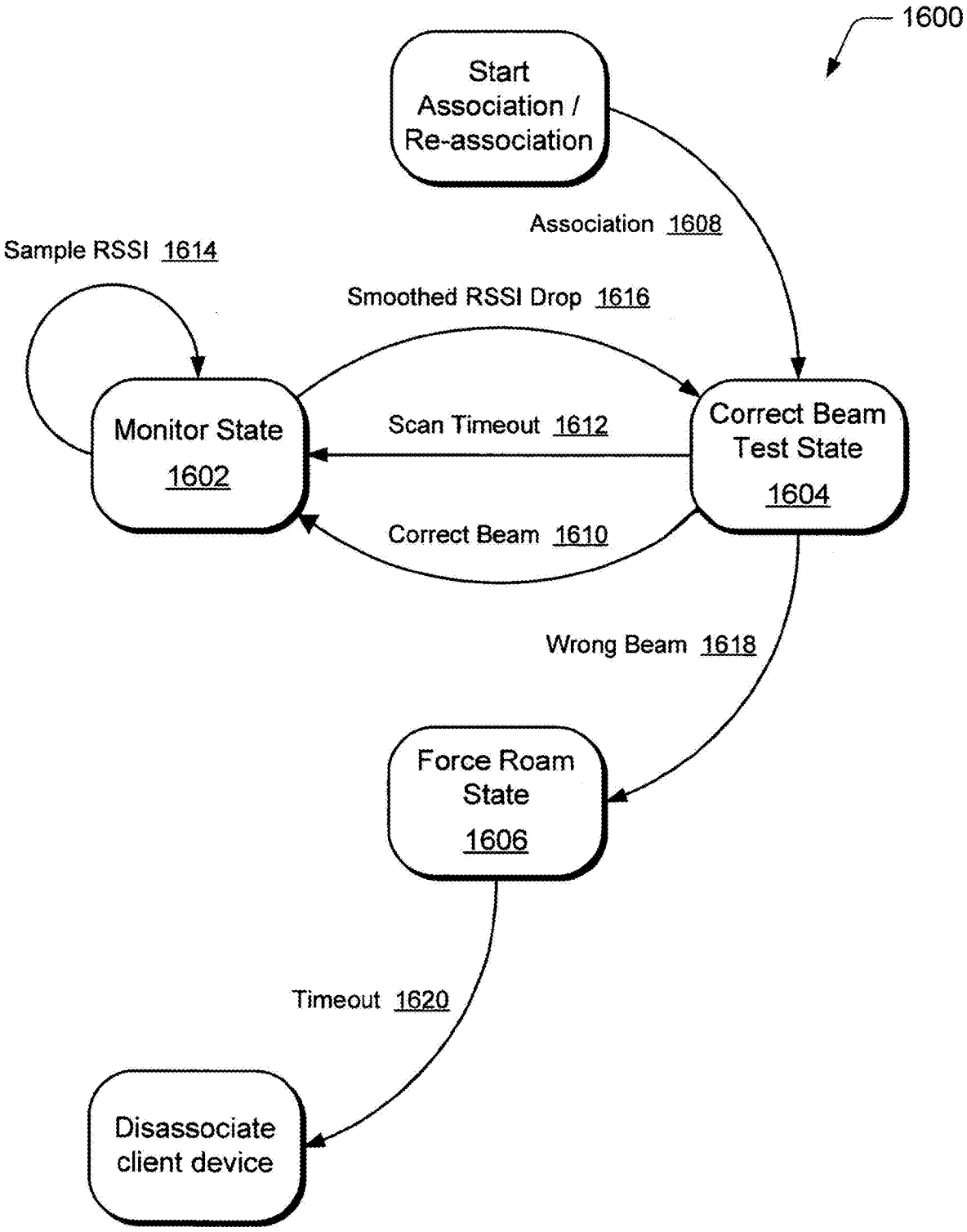
1600
Start Association / Re-association
Association 1608
Sample RSSI 1614
Smoothed RSSI Drop 1616
Monitor State 1602
Scan Timeout 1612
Correct Beam Test State 1604
Correct Beam 1610
Wrong Beam 1618
Force Roam State 1606
Timeout 1620
Disassociate client device

Fig. 16

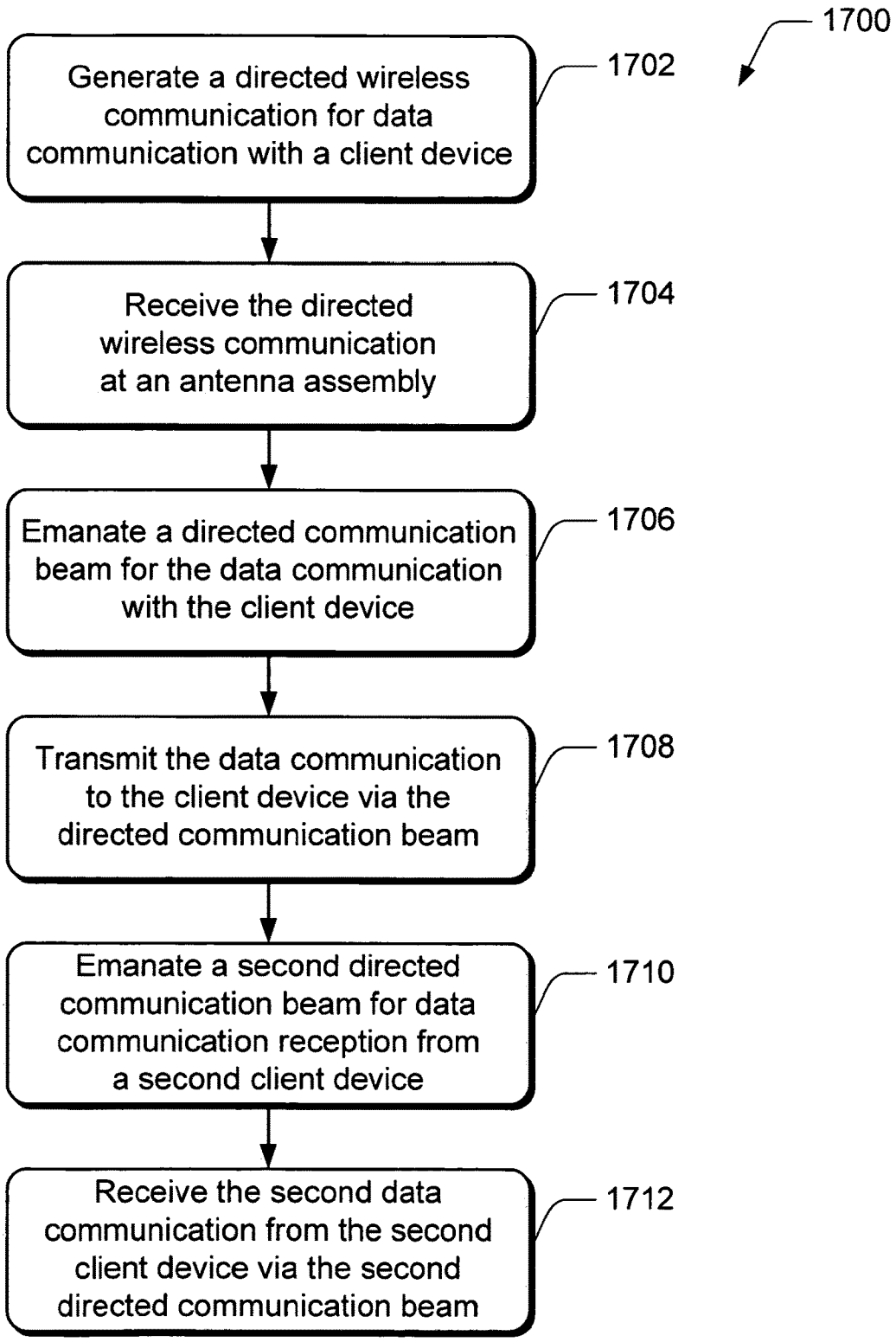
1700
Generate a directed wireless communication for data communication with a client device
1702
Receive the directed wireless communication at an antenna assembly
1704
Emanate a directed communication beam for the data communication with the client device
1706
Transmit the data communication to the client device via the directed communication beam
1708
Emanate a second directed communication beam for data communication reception from a second client device
1710
Receive the second data communication from the second client device via the second directed communication beam
1712

Fig. 17

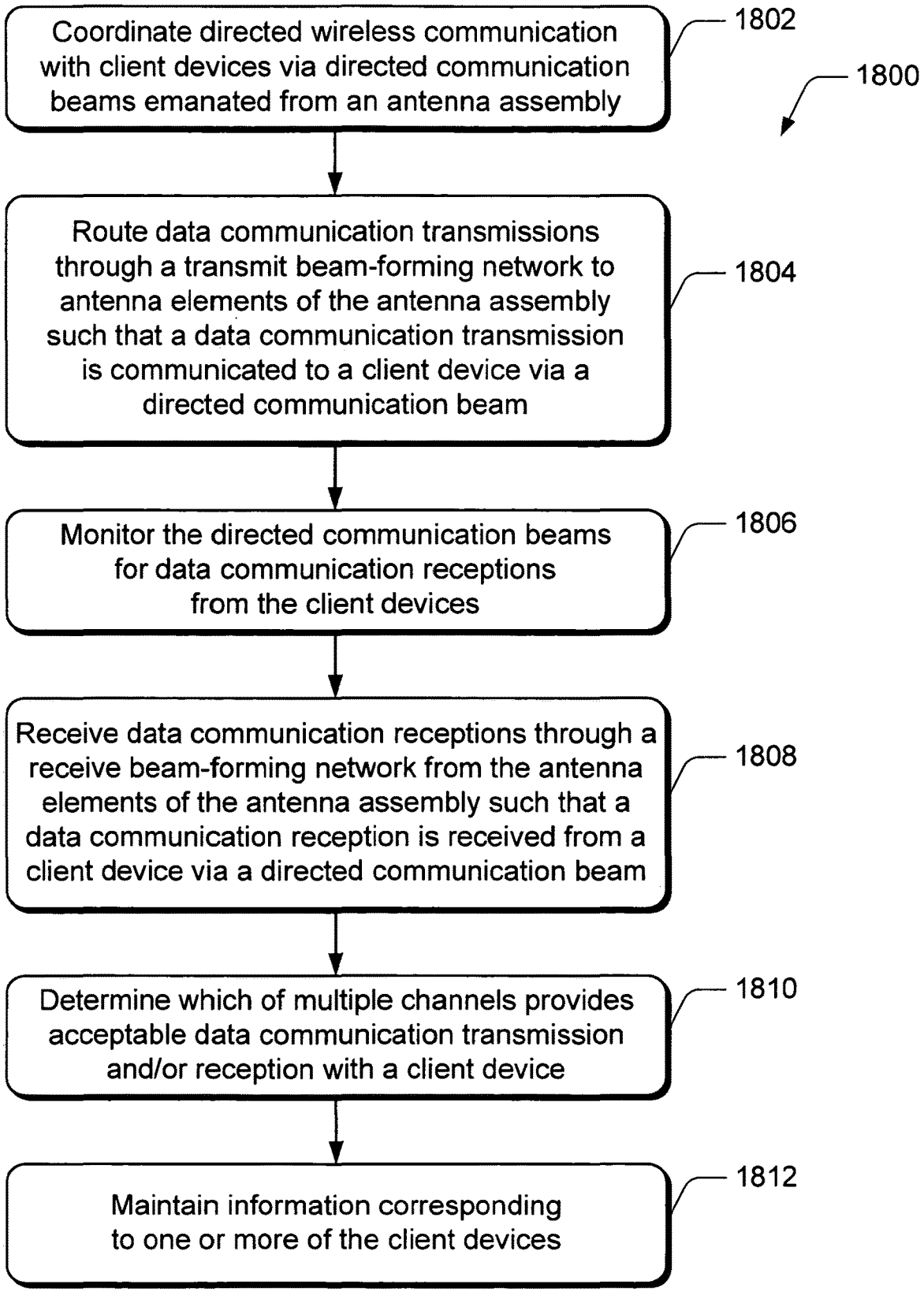
Coordinate directed wireless communication with client devices via directed communication beams emanated from an antenna assembly
1802
1800
Route data communication transmissions through a transmit beam-forming network to antenna elements of the antenna assembly such that a data communication transmission is communicated to a client device via a directed communication beam
1804
Monitor the directed communication beams for data communication receptions from the client devices
1806
Receive data communication receptions through a receive beam-forming network from the antenna elements of the antenna assembly such that a data communication reception is received from a client device via a directed communication beam
1808
Determine which of multiple channels provides acceptable data communication transmission and/or reception with a client device
1810
Maintain information corresponding to one or more of the client devices
1812

Fig. 18

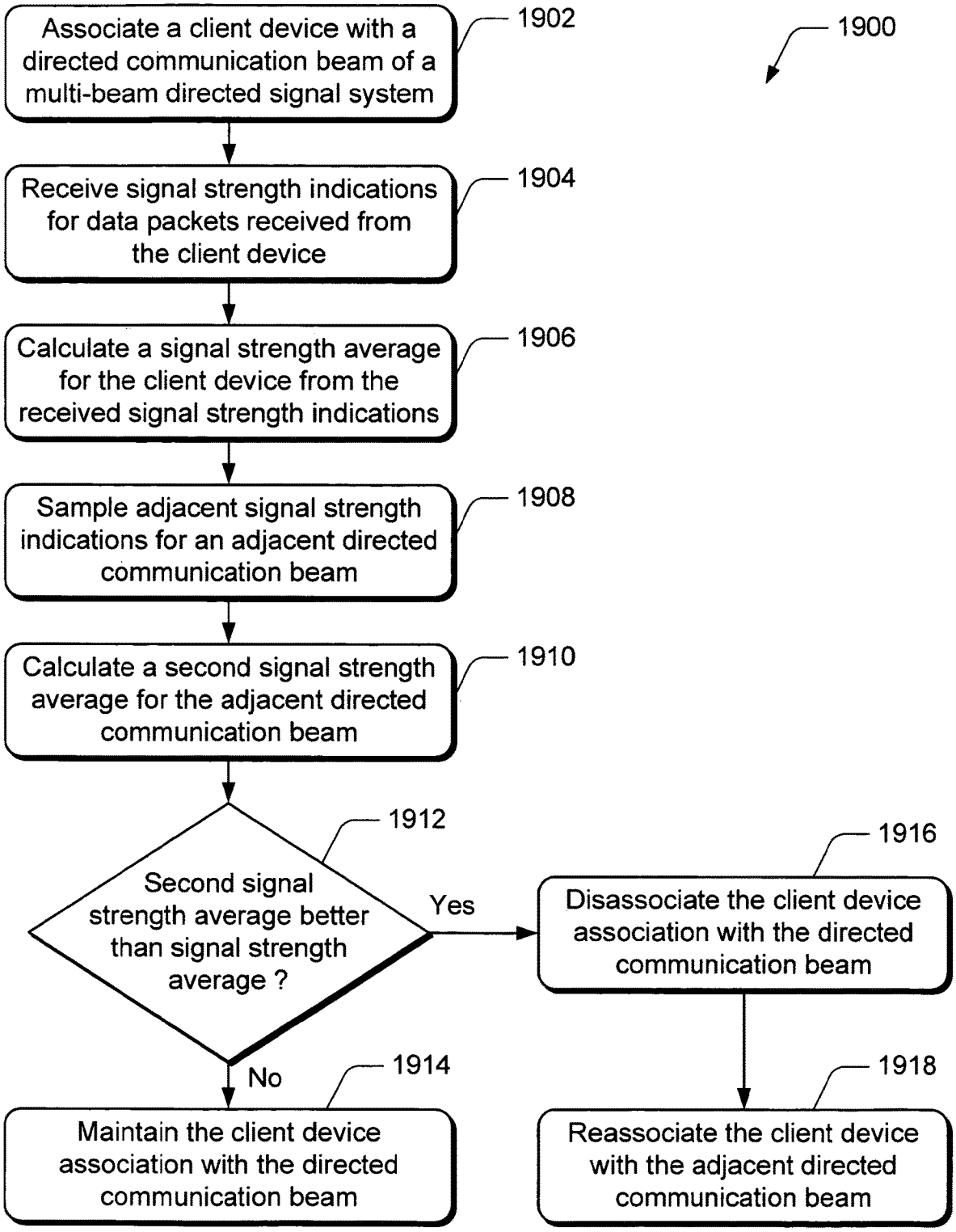
1900
Associate a client device with a directed communication beam of a multi-beam directed signal system
1902
Receive signal strength indications for data packets received from the client device
1904
Calculate a signal strength average for the client device from the received signal strength indications
1906
Sample adjacent signal strength indications for an adjacent directed communication beam
1908
Calculate a second signal strength average for the adjacent directed communication beam
1910
Second signal strength average better than signal strength average ?
1912
Yes
No
Disassociate the client device association with the directed communication beam
1916
Maintain the client device association with the directed communication beam
1914
Reassociate the client device with the adjacent directed communication beam
1918

Fig. 19

DIRECTED WIRELESS COMMUNICATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 15/260,147, filed Sep. 8, 2016, which is a continuation application of U.S. patent application Ser. No. 13/855,410, filed on Apr. 2, 2013 (now U.S. Pat. No. 9,462,589), which is a divisional application of U.S. patent application Ser. No. 10/700,329, filed on Nov. 3, 2003 (now U.S. Pat. No. 8,412,106), which claims the benefit of U.S. Provisional Application No. 60/423,660, filed on Nov. 4, 2002. Each of the above-referenced patent applications is incorporated herein by reference in its entirety.

BACKGROUND

The following disclosure relates to directed wireless communication.

Computing devices and other similar devices implemented to send and/or receive data can be interconnected in a wired network or wireless network to allow the data to be communicated between the devices. Wired networks, such as wide area networks (WANs) and local area networks (LANs) for example, tend to have a high bandwidth and can therefore be configured to communicate digital data at high data rates. One obvious drawback to wired networks is that the range of movement of a device is constrained since the device needs to be physically connected to the network for data exchange, For example, a user of a portable computing device will need to remain near to a wired network junction to maintain a connection to the wired network.

An alternative to wired networks is a wireless network that is configured to support similar data communications but in a more accommodating manner. For example, the user of the portable computing device can move around within a region that is supported by the wireless network without having to be physically connected to the network. A limitation of conventional wireless networks, however, is their relatively low bandwidth which results in a much slower exchange of data than a wired network. Further, conventional wireless networks are implemented with multiple base stations, or access points, that relay communications between wireless-configured devices. These conventional access points have a limited communication range, typically 20 to 200 feet, and a wireless network requires a large number of these access points to cover and provide a communication link over a large area.

Many conventional wireless communication systems and networks implement omni-directional antennas to transmit data packets to a client device and receive data packets from or via an access point. With a standard wireless LAN, for example, a transmission is communicated equally in all directions from an omni-directional antenna, or point of emanation. Receiving devices located within range and positioned at any angle with respect to the emanating point can receive the wireless transmission.

However, standard omni-directional wireless LANs or omni-directional wireless wide area networks (WANs) have drawbacks and limitations. For example, transmission range is limited and electromagnetic interference associated with transmissions is unmanaged and can interfere with or otherwise restrict the use of other communicating devices that operate in the same frequency band within the transmission coverage area. Furthermore, inefficiencies and data corruption can occur if two or more centralized points of emanation are positioned proximate to have overlapping coverage areas.

SUMMARY

Directed wireless communication is described herein. In an implementation, a multi-beam directed signal system coordinates directed wireless communication with client devices. A transmit beam-forming network routes data communication transmissions to the client devices via directed communication beams that are emanated from an antenna assembly, and a receive beam-forming network receives data communication receptions from the client devices via the directed communication beams.

BRIEF DESCRIPTION OF THE DRAWINGS

The same numbers are used throughout the drawings to reference like features and components.

FIG. **1** illustrates an exemplary wireless communications environment.

FIG. **2** illustrates an exemplary directed wireless communication system.

FIG. **3** illustrates an exemplary communication beam array which can be generated with the exemplary directed wireless communication system shown in FIG. **2**.

FIG. **4** illustrates an exemplary antenna array for an antenna assembly as shown in FIG. **3**.

FIG. **5** illustrates an exemplary implementation of the directed wireless communication system shown in FIG. **2**.

FIG. **6** illustrates an exemplary set of communication beams that emanate from an antenna array of an antenna assembly as shown in FIG. **3**.

FIG. **7** illustrates an exemplary multi-beam directed signal system that establishes multiple access points.

FIGS. **8**A and **8**B illustrate various components of a multi-beam directed signal system and an antenna assembly of the directed wireless communication system shown in FIG. **2**.

FIG. **9** illustrates an exemplary multi-beam directed signal system that includes various components such as medium access controllers (MACs), baseband units, and MAC coordinator logic.

FIG. **10** further illustrates various components of the exemplary multi-beam directed signal system shown in FIG. **9**.

FIG. **11** illustrates a state transition diagram for a medium access controller (MAC).

FIG. **12** illustrates a multi-beam directed signal system receiving and weighting various communication signals.

FIG. **13** illustrates an exemplary multi-beam directed signal system that includes various component implementations.

FIG. **14** further illustrates a component implementation of the multi-beam directed signal system for complementary beam-forming.

FIG. **15** illustrates a graph depicting a signal level output (dB) for the component implementation shown in FIG. **14**.

FIG. **16** illustrates a state transition diagram for a roaming client device in wireless communication with a multi-beam directed signal system as shown in FIG. **2**.

FIG. **17** is a flow diagram of an exemplary method for a directed wireless communication system implemented with a multi-beam directed signal system and antenna assembly.

FIG. **18** is a flow diagram of an exemplary method for a directed wireless communication system implemented with a multi-beam directed signal system and antenna assembly.

FIG. **19** is a flow diagram of an exemplary method for client device roaming in a directed wireless communication system.

DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS

Directed wireless communication is described in which a multi-beam directed signal system is implemented to communicate over a wireless communication link via an antenna assembly with client devices implemented for wireless communication within the wireless system. The directed wireless communication system can be implemented to communicate with multiple devices, such as portable computers, computing devices, and any other type of electronic and/or communication device that can be configured for wireless communication. Further, the multiple electronic and/or computing devices can be configured to communicate with one another within the wireless communication system. Additionally, a directed wireless communication system can be implemented as a wireless local area network (WLAN), a wireless wide area network (WAN), a wireless metropolitan area network (MAN), or as any number of other similar wireless network configurations.

The following description identifies various systems and methods that may be included in such directed wireless communication systems and networks. It should be noted, however, that these are merely exemplary and that not all of the techniques described herein need be implemented in a given wireless system or network. Furthermore, many of the exemplary systems and methods described herein are also applicable and/or adaptable for use in other communication systems and networks.

Directed wireless communication provides improved performance over conventional wireless network arrangements by utilizing multi-beam receiving and/or transmitting adaptive antennas, when practical. In an implementation, simultaneous transmission and reception may occur at a wireless routing device by applying multi-channel techniques. In a described implementation, a multi-beam directed signal system (e.g., also referred to as an access point or Wi-Fi switch) is a long-range packet switch designed to support 802.11b clients in accordance with an 802.11 standard. An increase in communication range is achieved by beam-forming directed communication beams which simultaneously transmit directed signals and receive communication signals from different directions via receive and transmit beam-forming networks.

The multi-beam directed signal system establishes multiple point-to-point links (e.g., directed communication beams) by which data packets can be communicated. The point-to-point links have a communication range that covers a much larger area than conventional access points, eliminating the need for multiple communication access points and significantly reducing the complexity and cost of a wireless LAN (WLAN) network. Further, a client device can use a conventional wireless card to communicate with the multi-beam directed signal system over long distances with no modification of the client device. Accordingly, directed wireless communication as described herein represents a significant improvement over conventional wireless networks that use switched beam and/or omni-directional antennas.

FIG. **1** illustrates an exemplary wireless communications environment **100** that is generally representative of any number of different types of wireless communications environments, including but not limited to those pertaining to wireless local area networks (LANs) or wide area networks (WANs) (e.g., Wi-Fi compatible) technology, cellular technology, trunking technology, and the like. In wireless communications environment **100**, an access station **102** communicates with remote client devices **104**(**1**), **104**(**2**), . . . , **104**(N) via wireless communication or communication links **106**(**1**), **106**(**2**), . . . , **106**(N), respectively. Although not required, access station **102** is typically fixed, and remote client devices **104** may be fixed or mobile. Although only three remote client devices **104** are shown, access station **102** can wirelessly communicate with any number of different client devices **104**.

A directed wireless communication system, Wi-Fi communication system, access station **102**, and/or remote client devices **104** may operate in accordance with any IEEE 802.11 or similar standard. With respect to a cellular system, for example, access station **102** and/or remote client devices **104** may operate in accordance with any analog or digital standard, including but not limited to those using time division/demand multiple access (TDMA), code division multiple access (CDMA), spread spectrum, some combination thereof, or any other such technology.

Access station **102** can be implemented as a nexus point, a trunking radio, a base station, a Wi-Fi switch, an access point, some combination and/or derivative thereof, and so forth. Remote client devices **104** may be, for example, a hand-held device, a desktop or laptop computer, an expansion card or similar that is coupled to a desktop or laptop computer, a personal digital assistant (FDA), a mobile phone, a vehicle having a wireless communication device, a tablet or hand/palm-sized computer, a portable inventory-related scanning device, any device capable of processing generally, some combination thereof, and the like. Further, a client device **104** may be any device implemented to receive and/or transmit information (e.g., in the form of data packets) via the applicable wireless communication links **106**. Remote client devices **104** may also operate in accordance with any standardized and/or specialized technology that is compatible with the operation of access station **102**.

FIG. **2** illustrates an exemplary directed wireless communication system **200** that can be implemented in any form of a wireless communications environment **100** as described with reference to FIG. **1**. The directed wireless communication system **200** includes an access station **102** and remote client devices **202** and **204**. The access station **102** includes a multi-beam directed signal system **206** coupled to an antenna assembly **208** via a communication link **210**. In this example implementation, access station **102** is coupled to an Ethernet backbone **212**.

The antenna assembly **208** can be implemented as two or more antennas, and optionally as a phased array of antenna elements, to emanate multiple directed communication beams **214**(**1**), **214**(**2**), . . . , **214**(N). The antenna assembly **208** is an unobtrusive indoor or outdoor Wi-Fi antenna panel that can include various operability components such as RF devices and components, a central processing unit, a power supply, and other logic components. The antenna assembly can be implemented as a lightweight and thin structure that can be mounted on a wall or in a corner of a room to provide wireless communication over a broad coverage area, such as throughout a building and surrounding area, or over an expanded region, such as a college campus or an entire corporate or manufacturing complex. While the antenna

assembly may be applicable or adaptable for use in many other communication systems, the antenna assembly is described in the context of an exemplary wireless communications environment **100** (FIG. **1**).

The multi-beam directed signal system **206** can transmit and/or receive (i.e., transceive) information (e.g., in the form of data packets) by way of one or more directed communication beams **214** as a wireless communication via the antenna assembly **208**. Additionally, wireless communication(s) are transmitted and/or received from (i.e., transceived with respect to) a remote client device, such as client devices **202** and **204**. The wireless communications may be transceived directionally with respect to one or more particular communication beams **214**. The multi-beam directed signal system **206** can be implemented for multi-channel directed wireless communication. For example, client device **202** can communicate via directed communication beam **214**(**1**) with a first channel of the multi-beam directed signal system **206**, and client device **204** can communicate via directed communication beam, **214**(N) with a second channel of the multi-beam directed signal system **206**.

In the exemplary directed wireless communication system **200**, signals may be sent from a transmitter to a receiver using electromagnetic waves that emanate from one or more antenna elements of the antenna assembly **208** which are focused in one or more desired directions. For example, the multi-beam directed signal system generates a directed wireless communication for transmission to wireless client device **202** via directed communication beam **214**(**1**). This is in contrast to conventional omni-directional transmission systems that transmit a communication in all directions from an omni-directional antenna (e.g., example omni-directional transmission area **216** emanating from a central transmission point with reference to antenna assembly **208** and shown only for comparison). Although not to scale, the illustration depicts that the power to transmit over the omni-directional transmission area **216** can be directed as one or more communication beams over a farther distance **218** from a point of transmission (e.g., antenna assembly **208**).

When the electromagnetic waves are focused in a desired direction, the pattern formed by the electromagnetic wave is termed a "beam" or "beam pattern", such as a directed communication beam **214**. The production and/or application of such electromagnetic beams **214** is typically referred to as "beam-forming." Beam-forming provides a number of benefits such as greater range and/or coverage per unit of transmitted power, improved resistance to interference, increased immunity to the deleterious effects of multi-path transmission signals, and so forth. For example, a single communication beam **214**(**1**) can be directed for communication with a specific wireless-configured client device **202** and can be transmitted over a much greater distance **218** than would be covered by a conventional omni-directional antenna (e.g., example omni-directional transmission area **216** shown only for comparison).

FIG. **3** illustrates an exemplary communication beam array **300** of directed communication beams **214**(**1**), **214**(**2**), . . . **214**(N) that emanate from an antenna array **302** which is part of the antenna assembly **208**. Antenna assembly **208** is also referred to herein as an "adaptive antenna" which describes an arrangement that includes the antenna array **302** having a plurality of antenna elements, and operatively supporting mechanisms and/or components (e.g., circuits, logic, etc.) that are part of a wireless routing device and configured to produce a transmission pattern that selectively places transmission nulls and/or peaks in certain directions within an applicable coverage area.

A transmission peak of a directed communication beam **214** occurs in the transmission pattern **300** when a generated and particular amount of energy is directed in a particular direction. Transmission peaks are, therefore, associated with the signal path and/or communication beam to a desired receiving node, such as another wireless routing device or a wireless client device. In some cases, sidelobes to a communication beam may also be considered to represent transmission peak(s).

Conversely, a transmission null (e.g., not a communication beam) occurs in the transmission pattern when no transmission of energy occurs in a particular direction, or a relatively insignificant amount of energy is transmitted in a particular direction. Thus, a transmission null is associated with a signal path or lack of a communication beam towards an undesired, possibly interfering, device and/or object. Transmission nulls may also be associated with the intent to maximize power in another direction (i.e., associated with a transmission peak), to increase data integrity or data security, and/or to save power, for example. A determination to direct a transmission null and/or a transmission peak (e.g., a communication beam **214**) in a particular direction can be made based on collected or otherwise provided routing information which may include a variety of data associated with the operation of the multi-beam directed signal system **206**, wireless routing device, and other devices at other locations or nodes within the wireless network.

One or more of the communication beams **214**(**1**), **214**(**2**), . . . , **214**(N) are directed out symmetrically from antenna array **302** to communicate information (e.g., in the form of data packets) with one or more wireless client devices. The communication beam array **300** shown in FIG. **3** is merely exemplary and other communication beam arrays, or patterns, may differ in width, shape, number, angular coverage, azimuth, and so forth. Further, although all of the directed communication beams **214** are shown emanating from antenna array **302** at what would appear as a same time, transmission and reception via one or more communication beams **214** is controlled and coordinated with signal control and coordination logic **304** of the multi-beam directed signal system **206**.

The signal control and coordination logic **304** can monitor each of the directed communication beams **214** as an individual access point. Further, the signal control and coordination logic **304** can control a directed wireless transmission to a first client device and a directed wireless transmission from a second client device such that the directed wireless transmission does not interfere with the directed wireless reception. Optionally, a directed wireless transmission and a directed wireless reception can be simultaneous.

As used herein, the term "logic" (e.g., signal control and coordination logic **304**) refers to hardware, firmware, software, or any combination thereof that may be implemented to perform the logical operations associated with a given task. Such, logic can also include any supporting circuitry that may be required to complete a given task including supportive non-logical operations. For example, "logic" may also include analog circuitry, memory, input/output (I/O) circuitry, interface circuitry, power providing/regulating circuitry, etc.

The directed communication beams **214** of antenna array **302** can be directionally controllable, such as steerable in an analog implementation or stepable in a digital implementation. For example, a directed communication beam **214** can be directionally stepable by the width (e.g., degrees) of the communication beam to "steer" or "aim" addressable data packets when communicating with a client device. Further,

a communication beam **214** can be directionally controllable such that only an intended client device will receive a directed wireless communication via the communication beam **214**, and such that an unintended recipient will not be able to receive the directed wireless communication.

Although data signals (e.g., information as data packets) can be directed to and from a particular client device (e.g., client devices **202** and **204**) via one or more directed communication beams **214**, interference between communications beams **214** can occur. For example, a downlink signal transmission from antenna assembly **208** via communication beam **214**(**2**) can corrupt an uplink signal reception at antenna assembly **208** via communication beam **214**(**3**). The signal control and coordination logic **304** coordinates uplink and downlink signal transmissions across (e.g., between and/or among) the different communication beams **214** so as to avoid, or at least reduce, the frequency at which downlink directed signals are transmitted via a first communication beam (e.g., communication beam **214**(**2**)) while uplink directed signals are being received via a second communication beam (e.g., communication beam **214**(**3**)).

FIG. **4** illustrates an exemplary antenna array **302** (also referred to herein as an adaptive antenna) that is formed with an array of antenna elements **400**. Each antenna element **400** has multiple communication signal transfer slots **402** (e.g., transfer slots **402**(**1**) and **402**(**2**)) that are formed into a front surface **404** of an antenna element **400**. The antenna array **302** transmits and receives data as electromagnetic communication signals via the transfer slots **402** in each antenna element **400**.

In an exemplary implementation, the communication signal transfer slots **402** in an antenna element **400** are formed into two parallel slot rows **406**(**1**) and **406**(**2**) in which the transfer slots **402**(**1**) in slot row **406**(**1**) are staggered, or otherwise offset, in relation to the transfer slots **402**(**2**) in slot row **406**(**2**). Each transfer slot **402**(**1**) in slot row **406**(**1**) is offset from each transfer slot **402**(**2**) in slot row **406**(**2**) in a direction **408** and a distance **410**. For example, transfer slot **402**(**1**) in slot row **406**(**1**) is offset from transfer slot **402**(**2**) in slot row **408**(**2**) in a direction that is parallel to the slot rows **406** (e.g., the direction **408**) over a distance that is approximately the length of one rectangular transfer slot **402** (e.g., the distance **410**). The distance **410** between transfer slots **402** in a slot row **406** is approximately the antenna element wavelength $\lambda_g/2$ apart.

The gain of an adaptive antenna (e.g., antenna array **302**) is dependent on the implementation of the multi-beam directed signal system **206**. However, for a uniformly illuminated antenna array, the antenna gain is related to its effective aperture by an equation:

$$G_R = \frac{4\pi \cdot A_{eff}}{\lambda^2}$$

Assuming A_{eff} is equal to a cross-sectional area of the antenna array:

$$G_R = \frac{4\pi \cdot w \cdot h}{\lambda^2}$$

where w is the width of the antenna, h is the height of the antenna, and λ is the wavelength. For an example indoor implementation of an antenna array where w=8λ and h=4λ, the antenna gain is determined by the equation:

$$G_R = \frac{4\pi \cdot 8\lambda \cdot 4\lambda}{\lambda^2} = 128\pi = 26\,\mathrm{dB}i$$

For an example outdoor implementation of an antenna array where w=8λ and h=8λ, the antenna gain is determined by the equation:

$$G_R = \frac{4\pi \cdot 8\lambda \cdot 8\lambda}{\lambda^2} = 256\pi = 29.1\,\mathrm{dB}i$$

When dissipation losses are zero, the antenna gain is equivalent to directivity. The effective aperture may include the effect of losses, and therefore the formulas may be used to calculate the gain. When the actual dimensions of the antenna array **302** are used as the "effective area", the losses are assumed to be zero (e.g., for an ideal implementation).

In this example illustration, the antenna array **302** is shown configured for indoor use with sixteen antenna elements (e.g., sixteen of antenna elements **400** formed or otherwise positioned together) each having two parallel rows of four communication signal transfer slots each (e.g., slot rows **406**(**1**) and **406**(**2**)). The antenna array **302** can be configured for outdoor use with thirty-two antenna elements (e.g., multiple antenna elements **400**) each having two parallel rows of eight communication signal transfer slots each, or can be configured as a larger antenna array or antenna panel with more antenna elements having more communication signal transfer slots per slot row. The antenna array **302** can be configured with as many antenna elements **400** having any number of transfer slots **402** per slot row **406** as needed to provide communication signal transfer (e.g., wireless communication) over a region or desired coverage area.

FIG. **5** illustrates an exemplary implementation **500** of a directed wireless communication system (e.g., directed wireless communication system **200** shown in FIG. **2**) that includes antenna assembly **208** and antenna array **302** as shown in FIG. **4**. In this example, antenna array **302** is positioned outside of a building **502** and mounted on an adjacent building **504** to provide wireless communication throughout building **502** and throughout a region **506** outside of building **502**. The antenna array **302** is coupled to the multi-beam directed signal system **206** (FIG. **2**) which can be communicatively coupled via a LAN connection, for example, to a server computing device positioned in building **504**. The server computing device can be implemented to administrate and control the associated functions and operations of the directed wireless communication system **200**. Alternatively, antenna array **302** can be mounted within building **502** to provide wireless communication throughout building **502** and throughout the region **506** outside of building **502**. For example, antenna array **302** can be mounted in a corner between two interior perpendicular walls to provide wireless communication coverage throughout the coverage area (e.g., building **502** and region **506** outside of the building).

The directed wireless communication system **200** (e.g., shown in implementation **500**) provides wireless communication of information (e.g., in the form of data packets) via directed communication beams **508**(**1**), **508**(**2**), . . . , **508**(N) to any number of electronic and/or computing client devices that are configured to recognize and receive transmission signals from the antenna array **302**. Any one or more of the electronic and computing client devices may also transmit

information via the directed communication beams **508**. Such electronic and computing devices can include printing devices, desktop and portable computing devices such as a personal digital assistant (PDA), cellular phone, and similar mobile communication devices, and any other type of electronic devices configured for wireless communication connectivity throughout building **502**, as well as portable devices outside of building **502**, such as computing device **510** within region **506**. One or more of the electronic and computing client devices may also be connected together via a wired network and/or communication link.

FIG. **6** illustrates an exemplary set or array of communication beams **600** that emanate from an antenna array **302** as shown in FIGS. **3** and **4**. In a described implementation, antenna array **302** can include sixteen antenna elements **400**(**0**, **1**, . . . , **14**, and **15**) (not explicitly shown in FIGS. **4** and **6**). From the sixteen antenna elements **400**(**0**-**15**), sixteen different communication beams **602**(**0**), **602**(**1**), . . . , **602**(**15**) are formed as the wireless communication signals emanating from antenna elements **400**(**0**-**15**) which may add and/or subtract from each other during electromagnetic propagation.

Communication beams **602**(**1**), **602**(**15**) spread out, or are directed out, symmetrically from a central communication beam **602**(**0**). The narrowest beam is the central beam **602**(**0**), and the beams become wider as they spread outward from the central beam. For example, beam **602**(**15**) adjacent beam **602**(**0**) is slightly wider than beam **602**(**0**), and beam **602**(**5**) is wider than beam **602**(**15**). Also, beam **602**(**10**) is wider still than beam **602**(**5**). The communication beam pattern of the set of communication beams **600** illustrated in FIG. **6** are exemplary only and other communication beam pattern sets may differ in width, shape, number, angular coverage, azimuth, and so forth.

Due to implementation effects of the interactions between and among the wireless signals as they emanate from antenna array **302** (e.g., assuming a linear antenna array in a described implementation), communication beam **602**(**8**) is degenerate such that its beam pattern is formed on both sides of antenna array **302**. These implementation effects also account for the increasing widths of the other beams **602**(**1**-**7**) and **602**(**15**-**9**) as they spread outward from the central communication beam **602**(**0**). In addition to the implementation effects of the interactions between and among the wireless signals, an obliquity effect explains that an azimuth beamwidth is related to the projected horizontal dimension of the array, as viewed from an oblique angle. Accordingly, the array appears narrower when viewed from an oblique angle, and therefore has a wider beamwidth as compared to a beamwidth viewed from a perpendicular angle. Beamwidth and directivity are inversely proportional and an obliquity factor (i.e., cos(azimuth angle)) defines a reduction in antenna array directivity at oblique angles and thus an increase in beamwidth. In a further implementation, communication beams **602**(**7**) and **602**(**9**) may be too wide for efficient and productive use. Hence, communication beams **602**(**7**), **602**(**8**), and **602**(**9**) are not used and the implementation utilizes the remaining thirteen communication beams **602** (e.g., communication beams **602**(**0**-**6**) and beams **602**(**10**-**15**)).

FIG. **7** illustrates an exemplary implementation **700** of the multi-beam directed signal system **206** which establishes multiple access points **702**(**1**), **702**(**2**), **702**(N). The multi-beam directed signal system **206** establishes any number access points **702** which can each correspond to, for example, an individual access point in accordance with an IEEE 802.11-based standard. Additionally, a wireless coverage area or region for each respective access point **702** may correspond to, for example, a respective directed communication beam **214** as shown in FIGS. **2** and **3**, or a respective communication beam **602** as shown in FIG. **6**.

Although communication signals directed into (or obtained from) different access points **702** may be directed at particular or specific coverage areas, interference between access points **702** can occur. For example, a downlink signal transmission for access point **702**(**2**) can destroy an uplink signal reception for access point **702**(**1**). Generally, signal control and coordination logic **304** coordinates uplink signal receptions and downlink signal transmissions across (e.g., between and/or among) different access points **702** so as to avoid, or at least reduce, the frequency at which downlink signals are transmitted at a first access point while uplink signals are being received at a second access point.

Specifically, signal control and coordination logic **304** is adapted to monitor the multiple access points **702**(**1**), **702**(**2**), . . . , **702**(N) to ascertain when a signal, or communication of information, is being received. When an access point **702** is ascertained to be receiving a signal, the signal control and coordination logic **304** limits (e.g., prevents, delays, etc.) the transmission of signals on the other access points **702** such that signal transmission does not interfere with signal reception. The monitoring, ascertaining, and restraining of signals can be based on and/or responsive to many factors. For example, the signals can be coordinated (e.g., analyzed and controlled) based on a per-channel basis.

FIGS. **8**A and **8**B illustrate various components of the multi-beam directed signal system **206** and the antenna assembly **208** both shown in FIGS. **2** and **3**. FIG. **8**A illustrates antenna array **302** which includes the sixteen antenna elements **400**(**0**, **1**, . . . , **15**) as described with reference to FIG. **6**. The antenna assembly **208** includes RF (radio frequency) components which are shown as a left transmit antenna board **800**, a right transmit antenna board **802**, a left receive antenna board **804**, and a right receive antenna board **806**. The multi-beam directed signal system **206** includes a transmit beam-forming network **808** and a receive beam-forming network **810**.

The left transmit antenna board **800** includes transmission logic **812**(**0**, **1**, **7**) and the right transmit antenna board **802** includes transmission logic **812**(**8**, **9**, . . . , **15**). Each transmission logic **812** (e.g., circuit, component, etc.) corresponds to an antenna element **400**(**0**-**15**) of the antenna array **302** and corresponds to a signal connection (e.g., node, port, channel, etc.) of the transmit beam-forming network **808**(**0**-**15**). Similarly, the left receive antenna board **804** includes reception logic **814**(**0**, **1**, . . . , **7**) and the right receive antenna board **806** includes reception logic **814**(**8**, **9**, **15**). Each reception logic **814** (e.g., circuit, component, etc.) corresponds to an antenna element **400**(**0**-**15**) of the antenna array **302** and corresponds to a signal connection (e.g., node, port, channel, etc.) of the receive beam-forming network **810**(**0**-**15**).

Generally, a beam-forming network **808** and **810** may include multiple ports for connecting to antenna array **302** and multiple ports for connecting to the multiple RF components, such as the transmit and receive antenna boards **800**-**806**. One or more active components (e.g., a power amplifier (PA), a low-noise amplifier (LNA), etc.) may also be coupled to the multiple ports on the antenna array side of a beam-forming network. Thus, antenna array **302** may be directly or indirectly coupled to a beam-forming network **808** and **810**.

Specifically, a beam-forming network **808** and **810** may include at least "N" ports for each of the multiple RF

transmission and receive logic components **812** and **814**, respectively. For example, each directed communication beam **214** (FIG. **2**) or **602** (FIG. **6**) emanating from antenna array **302** corresponds to an RF logic component **812** and/or **814**. Each RF logic component **812** and **814** can be implemented as, for example, a transmit and/or receive signal processor operating at one or more radio frequencies, with each frequency corresponding to a different channel. It should be noted that channels may be defined alternatively (and/or additionally) using a mechanism other than frequency, such as a code, a time slot, some combination thereof, and so forth.

FIG. **8**B further illustrates various components of the multi-beam directed signal system **206** which includes the signal control and coordination logic **304**, a multi-beam controller **816**, one or more memory components **818**, communication interface(s) **820**, a scanning receiver **822**, and receiver/transmitters (Rx/Tx) **824**(**0**, **1**, . . . , **15**). The multi-beam controller **816** (e.g., any of a processor, controller, logic, circuitry, etc.) can be implemented to control channel assignments for communication signals and data communication coordinated by the signal control and coordination logic **304**.

The channel assignments coordinated by the signal control and coordination logic **304** provide the best channel assignment for a signal based on given measurement information. Parameters of a channel assignment algorithm include:

ChannelAssignmentCycle which identifies a duration between changes in the channel assignment;

HeavyInterference which identifies an interference activity threshold. If, for example, interference activity is determined to be above this value, a particular channel may be considered deficient for the duration of time that the interference can be detected;

BadChannelThreshold which identifies a number of measurement periods (e.g., a MeasurementDuration) that a channel has interference activity above the HeavyInterference threshold; and

JamInterference which identifies an interference activity threshold above the HeavyInterference parameter.

Further, channel assignment internal parameters can include:

MeasurementCycle which identifies a time duration (e.g., twenty-four hours) in which a measurement is completed;

MeasurementDuration which identifies a time duration (e.g., minutes) between two measurement points;

PeakLoadLimit which identifies a maximum load allowed on one channel; and

ChannelSixBiasFactor which is a bias factor to compensate for transmission on channel six to reduce inter-modulation.

The scanning receiver **822** and the receiver/transmitters (Rx/Tx) **824** measure metrics of channel activity every specified MeasurementDuration during a cycle of MeasurementCycle. The metrics can include a number of associated client devices, throughput and packet error rates (PER) of each receiver/transmitter **824**, interference and channel utilization of each communication beam (e.g., frequency, or channel), and/or any number of other metrics. The channel activity metrics include:

$N_i(t)$ which is a number of associated clients of the ith Rx/Tx **824** and which is averaged over the MeasurementDuration period;

$S_i(t)$ which is the throughput of the ith Rx/Tx **824** measured in packets/second or bytes/second, and which is averaged over the MeasurementDuration period;

$P_i(t)$ which is a packet error rate (PER) of the ith Rx/Tx **824** and which is averaged over the MeasurementDuration period;

$D_i(t)$ which is a delay of the ith Rx/Tx **824** and which is averaged over the MeasurementDuration period;

$\rho_{ij}(t)$ which is channel utilization of the ith beam on the jth channel and which is measured by both the Rx/Tx **824** and scanning receiver **822** and averaged over the MeasurementDuration period. This is also referred to as a Channel Utilization Factor (CUF);

$Ns_j(t)$ which is a number of downlink data packets transmitted on the jth channel and which is averaged over the MeasurementDuration period;

$Nr_{ij}(t)$ which is a number of correctly received uplink data packets transmitted by client devices associated with the ith beam on the jth channel, and which is averaged over the MeasurementDuration period;

$Nn_{ij}(t)$ which is a number of uplink data packets transmitted by client devices associated with other communication beams, and which are correctly received by the ith beam on the jth channel. This is measured by the scanning receiver **822** and is averaged over the MeasurementDuration period. This is also referred to as the Self Interference Metric (SIM);

$No_{ij}(t)$ which is a number of uplink data packets transmitted by the client devices from overlapping subnets and which are correctly received by the ith beam on the jth channel. This is measured by the scanning receiver **822** and is averaged over the MeasurementDuration period. This is also referred to as the Overlapping Subnet Interference (OSI);

$Ne_{ij}(t)$ which is a number of uplink data packets with Physical Layer Convergence Procedure (PLCP) or data Cyclic Redundancy Check (CRC) errors in the ith beam on the jth channel and which is measured by the scanning receiver **822** and averaged over the MeasurementDuration period. This is also referred to as the Unidentified Interference Metric (UIM); and

$I_{ij}(t)$ which is the interference of the ith beam on the jth channel and which is measured by the scanning receiver **822**.

These and other metrics can be maintained with a memory component **818** in a data table (or similar data construct) within the MeasurementCycle. When the cycle restarts, the data table can either be cleared or updated with some aging factor to identify past metrics.

The metric $I_{ij}(t)$ can be derived from other measurements when the receiver/transmitters **824** are on the same channel. In such cases, $I_{ij}(t)$ can be estimated by first estimating a total number of packets from any overlapping subnets by an equation:

$$NI_{ij}(t) = No_{ij}(t) + Ne_{ij}(t) \cdot \frac{No_{ij}(t)}{Nr_{ij}(t) + Nn_{ij}(t) + No_{ij}(t)}$$

Further, $I_{ij}(t)$ may be estimated by:

$$I_{ij}(t) = \frac{NI_{ij}(t)}{NS_i(t) + Nr_{ij}(t) + Nn_{ij}(t) + No_{ij}(t) + Ne_{ij}(t)} \cdot \rho_{ij}(t)$$

For channel assignment pre-processing, a channel that has interference activity which exceeds HeavyInterference for a BadChannelThreshold is not used. The interference activity is averaged over intervals of the MeasurementDuration period. In an implementation, a MeasurementCycle can

include forty-eight measurement intervals. A channel can be eliminated if the interference activity HeavyInterference exceeds the BadChannelThreshold for a specified number of periods.

The total number of active users (e.g., client devices) associated with any one directed communication beam **214** (FIG. **2**) or **602** (FIG. **6**) can be estimated by dividing the number of associated users of that communication beam by the percentage of time available to those users. The total number of users on beam i and channel j may therefore be described by:

$$N_{ij}(t) = \frac{N_i(t)}{1 - \tilde{} I_{ij}(t)}$$

where $\tilde{}I_{ij}(t)=\min\{I_{ij}(t), \text{HeavyInterference}\}$ which is the interference activity limited to a maximum allowable interference on a given communication beam. This ensures that the estimate does not provide large peaks due to an unusual period of high interference.

A block-based channel assignment algorithm assigns adjacent communication beams to the same frequency channel which minimizes the hidden beam problem as described further with reference to FIG. **14**. The algorithm allocates the thirteen communication beams into a maximum of three blocks, with each block assigned to one frequency channel (e.g., channels **1**, **6**, or **11**) so that the peak load on each channel is minimized. To determine an optimal solution, the boundaries between the assignment blocks (i.e. the number of communication beams in each block) and the frequency channel of each block is determined.

There are sixty-six possible combinations that divide thirteen communication beams into three blocks. For each of these possible combinations, the three blocks would be assigned to the three different channels. The number of channel permutations is six and the best channel-beam combination from three hundred, ninety-six (66×6=396) possible combinations can be determined. A factor $L_j(t)$ is denoted as the total load on the jth frequency channel at time (t) such that. $L_j^*=\max\{L_j(t)\}$ where t is of the set [0,T] which is the peak load on the jth channel in the last measurement period, and where T is the measurement cycle (i.e., MeasurementCycle). A combination can be determined that minimizes the peak load on all of the channels which can be described as $\min\{\max\{L_j^*\}\}$ where j is of the set $[f_1f_6f_{11}]$.

In an event that the overall network communication load, or traffic, is minimal, fewer than the three frequency channels may be used. A parameter PeakLoadLimit identifies a communication load limit below which only two of the frequency channels (e.g., channel **1** and channel **11**, for example) are used. If the peak communication load on either of the two channels exceeds the PeakLoadLimit, then the three frequency channels can be utilized.

The block-based channel assignment algorithm can be implemented to utilize two or three frequency channels. Initially, the thirteen communication beams are divided into two blocks of which there are twelve possible combinations. For each combination, the channel selections can be f_1f_6, f_1f_{11}, f_6f_1, f_6f_{11}, $f_{11}f_1$, or $f_{11}f_6$ such that there are a total of seventy-two block and channel combinations. Assuming that the kth block-channel combination has a configuration as follows:

Block 1: communication beams 0 to b_k (0 to N−2) are assigned to channel C_1; and

Block 2: communication beams b_k+1 to N−1 (1 to N−1) are assigned to channel C_2 Then the communication traffic load of channels C_1 and C_2 are:

$$L_{C1}^{ki}(t) = \sum_{i=0}^{b_k} N_{iC1}(t)$$

$$L_{C2}^{k}(t) = \sum_{i=b_k+1}^{N-1} N_{iC2}(t)$$

The peak communication load on the first block for combination k is denoted by:

$$PL_1(k)=\max\{L^k_{C1}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

$$PL_2(k)=\max\{L^k_{C2}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

And the peak communication load for the busiest block (e.g., channel) is:

$$PL_{max}(k)=\max\{PL_1(k),PL_2(k))\}$$

A combination index R with the least peak communication load is then selected such that $PL_{max}(R)=\min\{PL_{max}(k)\}$ where $(0\leq k\leq 71)$ which is the combination of channels and beams that minimize the peak load on any channel. If the peak load on a channel is not less than the PeakLoadLimit, then a three channel assignment can be implemented. Initially, the thirteen communication beams are divided into three blocks of which there are sixty-six possible combinations. For each combination, the channel selections can be $f_1f_6f_{11}$, $f_1f_{11}f_6$, $f_6f_1f_{11}$, $f_6f_{11}f_1$, $f_{11}f_1f_6$, or $f_{11}f_6f_1$ such that there are a total of three-hundred, ninety-six block and channel combinations. Assuming that the kth block-channel combination has a configuration as follows:

Block 1: communication beams 0 to b_k (0 to N−3) are assigned to channel C_1; and

Block 2: communication beams b_k+1 to p_k (1 to N−2) are assigned to channel C_2; and

Block 3: communication beams p_k+1 to N−1 (2 to N−1) are assigned to channel C_3;

Then the communication traffic load of channels C_1, C_2, and C_3 are:

$$L_{C1}^{ki}(t) = \sum_{i=0}^{b_k} N_{iC1}(t)$$

$$L_{C2}^{k}(t) = \sum_{i=b_k+1}^{p_k} N_{iC2}(t)$$

$$L_{C3}^{k} = \sum_{i=p_k+1}^{N-1} N_{iC3}(t)$$

The peak communication load on the first block for combination k is denoted by:

$$PL_1(k)=\max\{L^k_{C1}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

$$PL_1(k)=\max\{L^k_{C2}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

$$PL_3(k)=\max\{L^k_{C3}(t)\} \text{ where } t \text{ is of the set } [0,T],$$

and the peak communication load for the busiest block (e.g., channel) is:

$$PL_{max}(k)=\max\{PL_1(k),PL_2(k),PL_3(k)\}$$

A combination index R with the least peak communication load is then selected such that $PL_{max}(R)=\min\{PL_{max}(k)\}$ where $(0\leq k\leq 395)$ which is the combination of channels and beams that minimize the peak load on any channel.

When taking into account intermodulation such that channel combinations f_1f_6 and f_6f_{11} are to be avoided, then f_6 is avoided. Initially, the thirteen communication beams are divided into two blocks of which there are twelve possible combinations. For each combination, the channel selections can be f_1f_{11} and $f_{11}f_1$ such that there are a total of twenty-four block and channel combinations. Assuming that the kth block-channel combination has a configuration as follows:

Block 1: communication beams 0 to b_k (0 to N−2) are assigned to channel C_1; and

Block 2: communication beams b_k+1 to N−1 (1 to N−1) are assigned to channel C_2 Then the communication traffic load of channels f_1 and f_{11} is the sum of the loads of the communication beams assigned to those channels as follows:

$$L^k_{f1}(t)=\sum_{f_1} N_{if1}(t) \quad \forall (i\in f_1)$$

$$L^k_{f11}(t)=\sum_{f_{11}} N_{if11}(t) \quad \forall (i\in f_{11})$$

The peak communication load on the first block for combination k is denoted by:

$$PL_1(k)=\max\{L^k_{f1}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

$$PL_2(k)=\max\{L^k_{f11}(t)\} \text{ where } t \text{ is of the set } [0,T]$$

and the peak communication load for the busiest block (e.g., channel) is:

$$PL_{max}=\max\{PL_1(k),PL_2(k)\}$$

A combination index R with the least peak communication load is then selected such that $PL_{max}(R)=\min\{PL_{max}(k)\}$ where $(0\leq k\leq 71)$ which is the combination of channels and beams that minimize the peak load on any channel. If the peak load on a channel is not less than the PeakLoadLimit, then a three channel assignment can be implemented.

Memory component(s) **818** can maintain routing and signal information which can include transmit power level information, transmit data rate information, antenna pointing direction information, weighting information, constraints information, null/zero location information, peak location information, quality of service (QoS) information, priority information, lifetime information, frequency information, timing information, user and node authentication information, keep out area information, etc., that is associated with each sending and receiving communication channel of the wireless communication system and within the multi-beam directed signal system **206**. In an implementation, at least some of routing information can be maintained with memory component(s) **818** within one or more routing tables or similar data structure(s).

The routing table(s) or similar data structure(s) provide an information basis for each routing decision within the wireless communication system (e.g., multi-beam directed signal system **206**). By way of example, routing table(s) entries may include all or part of the following information: IP address (e.g., IPv6) of a node in the wireless network—e.g., as an index; 48-bit unique address—e.g., IEEE 802.1 MAC address; Protocol ID—e.g., IEEE 802.11, 802.16.1, etc.; Modulation method; Connection ID (CID) of a node—e.g., as used in an IEEE 802.16.1 MAC; Nominal direction to a node—e.g., one or two dimension; Nominal transmit power level to a node; Nominal received signal strength indicator (RSSI) level from a node; Nominal channel to transmit on, and perhaps a backup channel; Nominal channel to receive on, and perhaps a backup channel; Nominal transmission data rate, e.g., 6 Mbps-54 Mbps, or as available; Nominal receive data rate, e.g., 6 Mbps-54 Mbps, or as available; Known station interference nulls; and Unknown station interference nulls.

In an exemplary implementation, and within the structure of signal control/coordination logic **304**, the routing table(s) are configured to receive or include data and/or primitives (e.g., function calls) from an Internet Protocol (IP) layer and a medium access control (MAC) layer, and to instruct a physical (PHY) layer to provide media access through the MAC layer. Therefore, in some examples, a routing table is more than simply a data table (or other similar structure) since it may also perform or otherwise support controlling and/or scheduling functions.

The communication interface(s) **820** can be implemented as any one of a serial, parallel, network, or wireless interface that communicatively couples the multi-beam directed signal system **206** with other electronic and/or computing devices. For example, the multi-beam directed signal system **206** can be coupled with a wired connection (e.g., an input/output cable) via a communication interface **820** to a network switch that communicates digital information corresponding to a communication signal to a server computing device. Any of the communication interfaces **820** can also be implemented as an input/output connector to couple digital, universal serial bus (USB), local area network (LAN), wide area network (WAN), metropolitan area network (MAN), and similar types of information and communication connections.

The scanning receiver **822** scans each directed communication beam (e.g., directed communication beams **214** shown in FIGS. **2** and **3**) consecutively and monitors for client devices and associated information such as the transmit power of a client device, roaming status, and the many other communication factors to update data that is maintained about each client device that is in communication via a communication beam. In an implementation, the scanning receiver **822** can be described in two operating states: a scan mode and a roaming mode. While operating in the scan mode, the scanning receiver **822** periodically scans the thirteen communication beams on the three channels and collects activity information to be maintained with the client device data.

FIG. **9** illustrates an exemplary multi-beam directed signal system **206** that includes various components such as medium access controllers (MACs) **900**, baseband units (BB) **902**, and MAC coordinator logic **904**. The multi-beam directed signal system **206** also includes radio frequency (RF) components **906** such as the left and right transmit antenna boards **800** and **802** (shown in FIG. **8**), respectively, and the left and right receive antenna boards **804** and **806**, respectively. This example also illustrates the antenna array **302**, the transmit beam-forming network **808** and the receive beam-forming network **810**, and an Ethernet switch and/or router **908**.

As described in the implementation with reference to FIG. **8**, antenna array **302** (e.g., via antenna assembly **208**) is coupled to the beam-forming networks **808** (transmit) and **810** (receive). The beam-forming networks **808** and **810** are coupled to multiple RF components **906**(**1**), **906**(**2**), . . . , **906**(N). Respective RF components **906**(**1**), **906**(**2**), . . . ,

906(N) are each coupled to a respective baseband unit 902(1), 902(2), . . . , 902(N) which are coupled to MAC coordinator logic 904. The Ethernet switch/router 908 is coupled to the multiple MACs 900(1), 900(2), . . . , 900(N) which are also each coupled to MAC coordinator logic 904.

In operation generally, each MAC 900 is associated with a respective baseband unit 902. Although not specifically shown in FIG. 9, each respective MAC 900 may also be communicatively coupled to a corresponding baseband unit 902. MAC coordinator logic 904 is configured to coordinate the activities of the multiple MACs 900 with regard to at least one non-associated respective baseband unit 902. For example, MAC coordinator logic 904 may forward an instruction to MAC 900(1) responsive, at least partly, to an indicator provided from baseband unit 902(2). MAC coordinator logic 904 can be implemented as hardware, software, firmware, and/or some combination thereof.

The Ethernet switch/router 908 is coupled to Ethernet backbone 212 (FIG. 2) and is configured to relay incoming packets from Ethernet backbone 212 to the appropriate MAC 900 to which they correspond. Ethernet switch/router 908 is also configured to relay outgoing packets from the multiple MACs 900 to Ethernet backbone 212. Ethernet switch/router 908 may be implemented using, for example, a general purpose central processing unit (CPU) and memory. The CPU and memory can handle layer-2 Internet protocol (IP) responsibilities, flow control, and so forth. When receiving packets from Ethernet backbone 212, Ethernet switch/router 908 obtains the destination port for the destination MAC 900 address. In this manner, an Ethernet switch and/or router may be realized using software (or hardware, firmware, some combination thereof, etc.).

The beam-forming networks 808 and 810, in conjunction with antenna array 302, form the multiple directed communication beams 214 (FIGS. 2 and 3), A beam-forming network can be implemented as an active or passive beam-former. Examples of such active and passive beam-formers include a tuned vector modulator (multiplier), a Butler matrix, a Rotman lens, a canonical beam-former, a lumped-element beam-former with static or variable inductors and capacitors, and so forth. Alternatively, communication beams may be formed using full adaptive beam-forming.

As described with reference to FIGS. 8A and 8B, a beam-forming network 808 and 810 may include multiple ports for connecting to antenna array 302 and additional ports for connecting to the multiple RF components 906. One or more active components (e.g., a power amplifier (PA), a low-noise amplifier (LNA), etc.) may also be coupled to the multiple ports on the antenna array side of the beam-forming networks 808 and 810. Thus, antenna array 302 may be directly or indirectly coupled to the beam-forming networks 808 and 810.

The beam-forming networks 808 and 810 may include at least "N" parts for each of the multiple RF components 906(1, 2, . . . , N). In an example implementation, each communication beam 214 emanating from antenna array 302 corresponds to an RF component 906. Each RF component 906 can be implemented as a transmit and/or receive signal processor operating at radio frequencies and each RF component 906 can operate at one or more frequencies, with each frequency corresponding to a different channel. It should be noted that channels may be defined alternatively (and/or additionally) using a mechanism other than frequency, such as a code, a time slot, a signal node, some combination thereof, and so forth.

As described above, each respective RF component 906 (1, 2, . . . , N) is coupled to a respective baseband unit 902(1, 2, N) and each respective MAC 900(1, 2, . . . , N) is associated with a corresponding baseband unit 902(1, 2, . . . , N). Although not illustrated in this example or required, each MAC 900 and associated respective baseband unit 902 may be located on individual respective electronic cards. Additionally, the respective RF component 906 to which each respective baseband unit 902 is coupled may also be located on the individual respective electronic cards.

Each respective MAC 900 and corresponding baseband unit 902 may be associated with a different respective access point, such as access points 702(1, 2, . . . , N) (FIG. 7). Each respective RF component 906, along with signal nodes (e.g., ports, communication nodes, etc.) of the beam-forming networks 808 and 810, and/or antenna array 302, and respective communication beams 214 may also correspond to the different respective access points 702. The MACs 900 are configured to control access to the media that is provided, at least partially, by baseband units 902. In this case, the media corresponds to the signals transmitted and/or received via communication beams 214 (FIGS. 2 and 3). These signals can be analog, digital, and so forth. In a described implementation, digital signals comprise one or more data packets.

In a packet-based environment, a data packet arriving at the multi-beam directed signal system 206 (or at access station 102) via a particular communication beam 214 from a particular remote client device 202 (FIG. 2) is received via the antenna array 302 and the beam-forming networks 808 and/or 810. The data packet is processed through a particular RF component 906 and a corresponding baseband unit 902. The data packet is then forwarded from baseband unit 902 to a corresponding MAC 900 which facilitates data packet communication via the Ethernet backbone 212 (FIG. 2) by Ethernet switch/router 908. Data packets arriving at the multi-beam directed signal system 206 (or at access station 102) via Ethernet switch/router 908 are transmitted to a remote client device 202 and/or 204 via directed communication beam(s) 214 in an opposite communication path. The transmission and reception of data packets via directed communication beams 214, as well as the forwarding of packets within the multi-beam directed signal system 206 is controlled at least partially by the MACs 900.

In a typical MAC-baseband environment, a MAC controls the associated baseband circuitry using input solely from the associated baseband circuitry. For example, if baseband circuitry indicates to its associated MAC that it is receiving a packet, then the associated MAC does not initiate the baseband circuitry to transmit a packet, which can jeopardize the integrity of the packet being received.

With co-located access points 702 (e.g., as in FIG. 7) and/or co-located pairs of MACs 900 and associated baseband units 902, a first access point 702(1) and/or a first MAC 900(1)/baseband unit 902(1) pair are unaware of the condition or state (e.g., transmitting, receiving, idle, etc.) of a second access point 702(2) and/or a second MAC 900(2)/baseband unit 902(2) pair, and vice versa. As a result, absent additional control and/or logic, a data packet being received by the first access point 702(1) and/or the first MAC 900(1)/baseband unit 902(1) pair can be corrupted (e.g., altered, destroyed, interfered with, rendered unusable for its intended purpose, etc.) by a transmission from the second access point 702(2) and/or the second MAC 900(2)/baseband unit 902(2) pair. This corruption may occur even though the packet reception and the packet transmission are effectuated using different communication beams 214(3) and 214(2), respectively, when the reception and transmission

occur on the same channel. Effectively, an incoming data packet reception via a first communication beam **214** can be rendered unsuccessful by an outgoing data packet transmission via a second communication beam **214** that occurs on the same channel and is overlapping.

As described above, MAC coordinator logic **904** is coupled to the multiple baseband units **902**(**1**, **2**, . . . , N) and to the multiple MACs **900**(**1**, **2**, . . . , N). The MAC coordinator logic **904** is configured to prevent MACs **900**(**1**, **2**, . . . , N) from generating or otherwise causing a transmission if at least one and optionally if any of the baseband units **902**(**1**, **2**, . . . , N) are receiving. For example, if baseband unit **902**(**2**) indicates that it is receiving a data packet, MAC coordinator logic **904** initiates that MACs **900**(**1**, **2**, . . . , N) refrain from generating or otherwise causing a data packet transmission during the data packet reception. Factors that can modify, tune, tweak, extend, etc. this data packet transmission restraint may include one or more of the MACs **900** enabling transmissions on different channel(s) from that of baseband unit **902**(**2**) which is receiving.

More specifically, each baseband unit **902** forwards a corresponding receive indicator to MAC coordinator logic **904** which monitors the baseband units **902**. The MAC coordinator logic **904** analyzes the receive indicators to generate constructive receive indicators that are communicated, or otherwise provided, to each of the MACs **900**. In a described implementation, each baseband unit **902** forwards a receive indicator that reflects whether and/or when a baseband unit **902** is currently receiving a signal. Optionally, not physically forwarding an indicator may constitute a receive indicator that reflects no signal is being received. After processing the different receive indicators, MAC coordinator logic **904** forwards the same constructive receive indicator to each MAC **900** based on multiple, and possibly all, receive indicators. The MAC coordinator logic **904** may provide different constructive receive indicators to at least different subsets of the MACs **900**.

The receive indicators forwarded to MAC coordinator logic **904** may be comprised of any one or more different indications from the baseband units **902**. For example, the receive indicators may comprise clear channel assessment (CCA) or busy/non-busy indications. Alternatively, the receive indicators may comprise indications of signal reception based on energy signals, cross-correlation signals, data signals, other transmit and/or control signals, some combination thereof, and so forth. Furthermore, a receive indicator may comprise an analog or digital indication (of one or more bits), the driving of one or more lines, the presentation of one or more messages, some combination thereof, and so forth.

The MAC coordinator logic **904** is configured to accept the receive indicators from the baseband units **902** and combine them in some manner to generate or otherwise produce the constructive receive indicator(s). For example, MAC coordinator logic **904** may "OR" the receive indicators together to generate the constructive receive indicator (s). Consequently, if any receive indicator from baseband units **902** indicates that a baseband unit is receiving a signal, then, the constructive receive indicator indicates to each MAC **900** that a reception is occurring on a directed communication beam **214** (and/or access point **702**) of the multi-beam directed signal system **206**. As a result, the MACs **900** that are provided with an affirmative constructive receive indicator do not cause their respective associated baseband units **902** to transmit.

The constructive receive indicators provided from MAC coordinator logic **904** may be comprised of any one or more different indications interpretable by the MACs **900**. For example, the constructive receive indicators may comprise an indication for one or more predetermined inputs, such as a CCA or busy/non-busy input of the MACs **900**. Alternatively, the constructive receive indicators may be input to a different type of do-not-transmit input, a specially-designed input, a message-capable input, some combination thereof, and so forth. Furthermore, a constructive receive indicator may comprise an analog or digital indication (of one or more bits), the driving of one or more lines, the presentation of one or more messages, some combination thereof, and the like.

FIG. **10** further illustrates various components of the multi-beam directed signal system **206** shown in FIG. **9** which includes the MACs **900**, baseband units **902**, and MAC coordinator logic **904**. In this example, the exemplary multi-beam directed signal system **206** includes thirteen MACs **900**(**1**, **2**, . . . , **13**) and thirteen baseband units **902**(**1**, **2**, . . . , **13**) that are associated respectively therewith. Thirteen baseband units **902**(**1**, **2**, . . . , **13**) and thirteen MACs **900**(**1**, **2**, . . . , **13**) are utilized in this exemplary multi-beam directed signal system **206** to comport with the efficiently usable communication beams **602**(**0-6**) and **602**(**10-15**) of the exemplary set of communication beams shown in FIG. **6**. However, the elements and features described with reference to FIG. **10** are applicable to multi-beam directed signal systems **206** and/or access stations **102** with more than or fewer than thirteen MACs **900** and associated baseband units **902**.

The baseband units **902**(**1**, **2**, . . . , **13**) are configured to communicate with MACs **900**(**1**, **2**, . . . , **13**), and vice versa, directly or indirectly without MAC coordinator logic **904** input. Specifically, control data may be transferred there between which may include, for example, data packets for wireless communication on communication beams **214** (FIGS. **2** and **3**), carrier sense multiple access/collision avoidance (CSMA/CA) type information, and so forth. The media access technique in 802.11 is based on a Carrier Sense Multiple Access (CSMA) operation in which a each station transmits only when it determines that no other station is currently transmitting. This tends to avoid collisions that occur when two or more stations transmit at the same time where a collision would typically require that a transmitted packet be retransmitted.

In this example, the baseband units **902**(**1**, **2**, . . . , **13**) forward receive indicators (**1**, **2**, . . . , **13**) to MAC coordinator logic **904**. The MAC coordinator logic **904** includes a receive indicators combiner **1000** which may be comprised of one or more of program coding, a field-programmable gate array, discrete logic gates, and so forth, and which may be implemented as hardware, software, firmware, and/or some combination thereof. Receive indicators combiner **1000** combines receive indicators (**1**, **2**, . . . , **13**) to generate constructive receive indicators (**1**, **2**, . . . , **13**). For example, receive indicators (**1**, **2**, . . . , **13**) may be combined using a logical "OR" functionality which ensures that if any one or more receive indicators of receive indicators (**1**, **2**, . . . , **13**) is indicating that a signal is being received, then the associated constructive receive indicators of constructive receive indicators (**1**, **2**, . . . , **13**) also indicate that a signal is being received.

The constructive receive indicators (**1**, **2**, . . . **13**) are provided or otherwise communicated to MACs **900**(**1**, **2**, . . . **13**), respectively, so that. MACs **900**(**1**, **2**, . . . , **13**) do not cause baseband units **902**(**1**, **2**, . . . , **13**) to transmit

a signal while another signal is being received. The baseband units **902**(**1**, **2**, . . . , **13**) and the MACs **900**(**1**, **2**, . . . , **13**) may be segmented or grouped by a characteristic and/or state, such as by wireless communication channels. When segmented or grouped, a constructive receive indicator of a given segment or group indicates to a MAC that a signal is being received and that no signal should therefore be transmitted when any receive indicator of that given segment or group indicates that a signal is being received (or when multiple receive indicators of that given segment or group indicate that multiple signals are being received).

The MAC coordinator logic **904** can be modified, adjusted, expanded, etc. based on any number of different factors that include channel assignment information **1002**, receive indicator enable information **1004**, timer logic **1006**, and scanning logic **1008**. Although illustrated as separate components, any one or combination of the channel assignment information **1002**, receive indicator enable information **1004**, timer logic **1006**, and/or scanning logic **1008** can be implemented together and/or as part of MAC coordinator logic **904** or as another component of a multi-beam directed signal system **206**.

Channel assignment information **1002** enables receive indicators (**1**, **2**, . . . , **13**) to be combined by the receive indicators combiner **1000** on a per-channel basis. As a result, constructive receive indicators (**1**, **2**, . . . , **13**) restrain signal transmissions from MAC **900** and baseband unit **902** pairs when a signal reception is occurring on the same channel, even if by a different MAC **900** and baseband unit **902** pair. A downlinked data packet that is transmitted on one channel while an uplinked data packet is being received on another channel does not usually cause the uplinked data packet to be corrupted. On the other hand, a downlinked data packet that is transmitted on a channel while an uplinked data packet is being received on the same channel does usually cause the uplinked data packet to be corrupted (e.g., indistinguishable, non-communicative, etc.), even if the transmission and reception occur via different communication beams **214** (FIGS. **2** and **3**).

Channel assignment information **1002** may be implemented as, for example, a vector that relates each MAC **900** and associated baseband unit **902** to one of two or more channels. Hence, prior to a combination generated by the receive indicators combiner **1000**, each respective receive indicator (**1**, **2**, . . . , **13**) can be mapped to a channel segmentation or grouping based on a wireless communication channel used by a corresponding MAC **900** and baseband unit **902** pair.

Receive indicator enable information **1004** provides information for receive indicators combiner **1000** that stipulates which receive indicators (**1**, **2**, . . . , **13**) are to be used in a combination operation to produce the constructive receive indicators (**1**, **2**, . . . , **13**). Thus, certain receive indicators may be excluded from the combination operation for one or more operational considerations. The receive indicator enable information **1004** may be implemented as, for example, a masking register **1010** that comprises a register with exclusionary bits for masking one or more of the receive indicators (**1**, **2**, . . . , **13**) from a combination operation of the receive indicators combiner **1000**. In a described implementation, masking register **1010** includes thirteen bits that correspond to the thirteen receive indicators (**1**, **2**, . . . , **13**), which correspond to the thirteen baseband units **902**(**1**, **2**, . . . , **13**).

Timer logic **1006** can be used for one or more factors and, although only shown once, may alternatively be implemented as multiple components in an exemplary multi-beam directed signal system **206** to account for multiple timer functions, or one implementation may be capable of handling multiple timer functions. Timer logic **1006** includes a watchdog timer **1012** and optionally watchdog interrupt enable information **1014**.

For a first factor, timer logic **1006** relates to individual receive indicators (**1**, **2**, . . . , **13**). A duration of watchdog timer **1012** is set equal to a maximum data packet duration (e.g., a maximum-allowed length of a data packet). Watchdog timer **1012** is started when a particular receive indicator begins indicating that a signal is being received and stopped when the particular receive indicator ceases indicating that the signal is being received. If watchdog timer **1012** is not tolled by an indication of signal reception cessation prior to its expiration, then the signal being received is likely to not be intended for multi-beam directed signal system **206**. In this case, timer logic **1006** may indicate that the baseband unit **902** corresponding to the particular receive indicator is not to be used in a combination operation. This exclusion indication may be effectuated using receive indicator enable information **1004** (e.g., by setting a bit in masking register **1010**).

For a second factor, timer logic **1006** relates to constructive receive indicators (**1**, **2**, . . . , **13**) on a per-channel basis. A duration of watchdog timer **1012** is set with consideration of a temporal threshold beyond which a problem or error should be contemplated to have occurred and hence investigated. Watchdog timer **1012** is started when a particular constructive receive indicator (or indicators) for a given channel begins indicating that a signal is being received on the given channel and stopped when the particular constructive receive indicator ceases indicating that the signal is being received on the given channel. If watchdog timer **1012** is not tolled by an indication of signal reception cessation prior to its expiration, then there is a likelihood that an error has occurred.

Watchdog interrupt enable information **1014** is used for this second factor, and it stipulates which channel(s) (and thus which constructive receive indicators) are enabled for interruption. If watchdog timer **1012** expires and the given channel is enabled in accordance with watchdog interrupt enable information **1014**, an interrupt is generated and provided to MAC coordinator logic **904** or another component of the multi-beam directed signal system **206**.

Scanning logic **1008** may act independently or interactively with any one or more of channel assignment information **1002**, receive indicator enable information **1004**, and timer logic **1006**. For example, scanning logic **1008** can scan across communication beams **214** using different channels on receive to detect which channel or channels have the least or lowest interference levels. This scanning may occur once, periodically, continuously, and the like. A channel assignment vector or similar for channel assignment information **1002** may be configured responsive to such scanning and interference determinations of scanning logic **1008**.

As another example, scanning logic **1008** may scan across communication beams **214** to detect the presence of other access points (e.g., non-co-located access points) that are causing interference on a regular or constant basis. The existence of an access point may be inferred by receiving a basic service set identifier (BSSID) being broadcast by another access point. When another access point is detected within a coverage area of a particular communication beam **214** (e.g., when an overlapping subnet is detected), scanning logic **1008** may interact with receive indicator enable information **1004** to mask out a corresponding receive indicator from a baseband unit **902** that corresponds to the particular

communication beam **214**. As a result, frequent receptions from the overlapping subnet do not constantly prevent baseband unit **902** and MAC **900** pairs on the same channel from transmitting.

In an exemplary implementation, multi-beam directed signal system **206** can be configured such that the receive indicators (**1**, **2**, . . . , **13**) correspond to the state of the clear channel assessment (CCA) output as detected by baseband units **902**(**1**, **2**, . . . , **13**), and the constructive receive indicators (**1**, **2**, . . . , **13**) correspond to the state of the clear channel assessment input to MACs **900**(**1**, **2**, . . . , **13**). Based on the values for receive indicators (**1**, **2**, . . . , **13**), channel assignment information **1002**, and receive indicator enable information **1004**, MAC coordinator logic **904** determines the constructive receive indicators (**1**, **2**, . . . , **13**) for each RF component **906** (FIG. **9**) (as provided via MACs **900**, baseband units **902**, etc.).

In an exemplary implementation, MAC coordinator logic **904** is configured to operate such that an indicator "channel_wide_busy" for each channel is defined, where channel_wide_busy is affirmative (e.g., active) if the receive indicator from any baseband units operating on that channel indicates that a signal is being received, excluding those baseband units whose receive indicator enable information is not set (e.g., in masking register **1010**). Further, MAC coordinator logic **904** sets the constructive receive indicator for a particular MAC **900** and baseband unit **902** pair to affirmative (e.g., busy) if the receive indicator for that baseband unit **902** indicates affirmative (e.g., busy), or if "channel_wide_busy" for the channel of the particular MAC **900** and baseband unit **902** pair is affirmative (e.g., active).

FIG. **11** illustrates a state transition diagram **1100** for a MAC controller **900** as shown in FIGS. **9** and **10**. MAC controller states include Defer **1102**, BackOff **1104**, Idle **1106**, TransmissionRTS (TxRTS) **1108**, WaitCTS **1110**, Transmission Data (TxData) **1112**, Wait Acknowledgement (WaitACK) **114**, Receive **1116**, Transmission Acknowledgement (TxACK) **1118**, and TransmissionCTS (TxCTS) **1120**. The state transition diagram **1100** also includes received frame types Data **1126** and RTS **1128**, as well as procedures Transmission okay (TxOK( )) **1122** and Transmission fail (TxFail( )) **1124**.

The TxOK( ) procedure **1122** removes bytes transmitted from an outgoing queue and resets retry counter(s) and a contention window. The TxFail( ) procedure **1124** increments a retry counter, checks that the number of retries has not been exceeded, and increases the contention window. The Receive state **1116** ends if there is a transmission or check error, if the carrier is lost, or when a duration indicated in a header has elapsed. If there is an error, the Defer state **1102** timeout is set to initiate. If a frame did not have an error and is not addressed to a particular station, and it's duration field is greater than the current timer value, then the timer is set to the value of the frame's duration field.

At the BackOff state **1104**, a backoff counter is decremented every slot time and a backoff count is saved if this state is exited due to a channel becoming busy. When the backoff counter decrements to zero and MAC service data units are queued to transmit, the contention window and retry counts are reset. A MAC service data unit is the payload carried by a MAC (e.g., in an 802.11 implementation which will typically be an Ethernet frame). The MAC **900** adds a MAC header and a 32-bit CRC to the MAC service data unit to form a MAC protocol data unit.

Additionally, the state transition diagram **1100** includes various functions that return logical value(s) to control state transitions such as data( ), short( ), more( ), busy( ), error( ), notforus( ), and nav( ). The diagram **1100** also includes PHY indications that initiate a state transition such as busy, timeout, new, transmission end (txend), and receive end (rxend). The PHY indications are asynchronous events (e.g., interrupts) that terminate states for a MAC controller **900**. An indication receive end (rxend) identifies that a receiver has detected the end of a frame or an error. An indication transmission end (txend) identifies that a receiver has completed sending a frame. A busy indication is a receiver indication that a channel is busy. A timeout indication is generated when a transition state timer has expired. A new indication identifies that a new frame has been queued.

A busy( ) function returns a receiver indication that a channel is busy, and an error( ) function indicates that a received frame had a CRC error. A notforus( ) function indicates that a frame was not addressed to a particular station, and a nav( ) function indicates that a timer has not expired. A data( ) function indicates that data is queued to send, and a short( ) function indicates that a MAC protocol data unit is shorter than an RTS Threshold and that there are additional data fragments to be sent from a current MAC controller. A more( ) function facilitates obtaining the additional data fragments.

FIG. **12** illustrates an exemplary implementation **1200** of the multi-beam directed signal system **206** that weighs signals received via antenna array **302**. Communication and/or data transfer signals are received from sources **1202** (e.g., sources A and B). The signals received from sources **1202** are considered desired signals because they are from nodes within the wireless routing network. Further, signals such as noise and WLAN interference associated with another external wireless system **1204** are not desired.

These signals, both desired and undesired, are received via antenna array **302** and are provided to the signal control and coordination logic **304** (shown in FIG. **3**) from the receiver/transmitters (Rx/Tx) **824**(**0**), **824**(**1**), . . . , **824**(N) (also shown in FIG. **8**B). In this example, the signal control and coordination logic **304** includes the scanning receiver **822** that is configured to update routing information **1206** with regard to the received signals. For example, scanning receiver **822** may identify information about different classes of interferers (e.g., known and unknown types) within the routing information **1206**. In this example, routing information **1206** includes connection indexed routing table(s) based on identification information, such as address information, CID, and the like. The routing table includes identifiers of the desired sources and other identifiers for the interferers ("Int"). Further, the routing table includes stored weighting values (w) each associated with a particular signal source **1202** (e.g., sources A and B). Other information such as "keep out" identifiers may also be included in this exemplary routing table.

A description of the received signal(s) can be stored in the routing table in the form of the pattern or weighting of the signal(s). In this example, a polynomial expansion in z, $w(z)=w_0+w_1z+w_2z^2+w_3z^3+w_4z^4+ \ldots +w_iz^i$ can be utilized to establish the values of the weights (w_i) to be applied to a weight vector. The routing table(s) may store such weighing patterns as a function of θ, or the zeroes of the polynomial, for example. One advantage of zero storage is that the zeros represent directions for communication that should be nulled out to prevent self-interference or interfering with other nodes or possibly other known wireless communication systems, such as WLAN **1204** that is not part of the wireless routing network, but is operating within at least a portion of a potential coverage area **1208** and frequency bands.

The polynomial expansion in z, w(z), and the zeroes may be calculated from each other and each may be stored. Updates can be generated frequently (e.g., in certain implementations, about every millisecond), and a zero storage system may be more advantageous in most wireless network environments because only a few values will change at a given time. Storing the weighting values will in general require changes to all of the weighting values w(i) when any change in the pattern occurs. Note that w(i) and A(θ) may be expressed as Fourier transform pairs (discrete due to the finite antenna element space). The w(i) is equivalent to a time domain impulse response (e.g., a time domain unit sample response) and the A(θ) is equivalent to the frequency response (e.g., an evaluation of w(z) sampled along a unit circle).

The stored weighting values associated with each connection, data signal, and/or source are utilized in a weighting matrix **1210** which operates to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix **1210**. Thus, as described herein, the multi-beam directed signal system **206** is configured to control the transmission amplitude frequency band and directionality of data packets to other nodes and assist in reducing the effects associated with received noise and interference (e.g., self interference and/or external interference). This is accomplished with the signal control and coordination logic **304** within the multi-beam directed signal system **206**.

FIG. **13** illustrates an exemplary multi-beam directed signal system **206** that includes an antenna array **302** and a Butler matrix **1300** implemented as a beam-forming network (e.g., transmit beam-forming network **808** and/or receive beam-forming network **810** shown in FIGS. **8**A and **8**B). The multi-beam directed signal system **206** also includes multiple signal processors (SPs) **1302** and one or more baseband processors (e.g., baseband units **902** described with reference to FIGS. **9** and **10**). Baseband processors **902** accept communication signals from and provide communication signals to the multiple receiver/transmitters **824** (FIG. **8**B). A separate baseband processor **902** may be assigned to each signal processor **1302**, or a single baseband processor **902** may be assigned to any number of the multiple signal processors **1302**.

Exemplary Butler matrix **1300** is a passive device that forms, in conjunction with antenna array **302**, communication beams **214** using signal combiners, signal splitters, and/or signal phase shifters. Butler matrix **1300** includes a first side with multiple antenna ports (designated by "A") and a second side with multiple transmit and/or receive signal processor ports (designated by "Tx/Rx"). The number of antenna ports and transmit/receive ports indicate the order of the Butler matrix **1300**, which in this example, includes sixteen antenna ports and sixteen transmit/receive ports. Thus, Butler matrix **1300** has an order of sixteen.

Although Butler matrix **1300** is so illustrated, the antenna ports and transmit/receive ports need not be distributed on separate, much less opposite, sides of a Butler matrix. Also, although not necessary, Butler matrices typically have an equal number of antenna ports and transmit and/or receive signal processor ports. Furthermore, although Butler matrices are typically of an order that is a power of two (e.g., 2, 4, 8, 16, 32, 64, . . . , 2^n), they may alternatively be implemented with any number of ports.

The sixteen antenna ports of Butler matrix **1300** are identified or otherwise numbered from A(**0**, **1**, . . . , **15**). Similarly, the sixteen transmit/receive ports are numbered from Tx/Rx(**0**, **1**, . . . , **15**). Antenna ports A(**0**-**15**) are coupled to and populated with sixteen antenna elements **400**(**0**), **400**(**1**), . . . , **400**(**15**), respectively. Likewise, transmit/receive ports Tx/Rx(**0**-**15**) are coupled to and populated with sixteen signal processors **1302**(**0**), **1302**(**1**), . . . , **1302**(**15**), respectively. These signal processors **1302** are also directly or indirectly coupled to baseband processors **902**. It should be noted that one or more active components (e.g., a power amplifier (PA), a low-noise amplifier (LNA), etc.) may also be coupled on the antenna port side of Butler matrix **1300**.

In an exemplary transmission operation, communication signals are provided from baseband processors **902** to the multiple transmit and/or receive signal processors **1302**. The multiple signal processors **1302** forward the communication signals to the transmit/receive ports Tx/Rx(**0**-**15**) of Butler matrix **1300**. After signal processing (e.g., signal combination, signal splitting, signal phase shifting, and the like), Butler matrix **1300** outputs communication signals on the antenna ports A(**0**-**15**). Individual antenna elements **400** wirelessly transmit the communication signals, as altered by Butler matrix **1300**, from the antenna ports A(**0**-**15**) in predetermined communication beam patterns. The communication beam patterns are predetermined by the shape, orientation, constituency, etc. of antenna array **302** and by the Butler matrix **1300** signal processing. In addition to transmissions, wireless signals such as wireless communications **106** (FIG. **1**) are received responsive to the communication beams **214** formed by antenna array **302** in conjunction with Butler matrix **1300** in an inverse process.

FIG. **14** further illustrates an exemplary modified Butler matrix **1300** for a complementary beam-forming, post-combining implementation, Complementary beam-forming is a technique to reduce the effect of communication beam nulls and increase sidelobe levels without a severe power penalty to the main beam. This is done to reduce the effect of the "hidden beam." As described below, increasing the range of 802.11 networks without increased transmit power and using standard clients is possible with adaptive antenna arrays, such as, for example, directional high-gain antennas. Using high gain antennas, it is possible to direct the energy in a given direction and hence increase the range in that direction.

Forming directional transmit communication beams has the side effect of hiding the transmitted energy from some client devices in a CSMA network (i.e., negatively impacting the carrier sense mechanism in the network). A client device measures the energy transmitted from access points and from other client devices. If the client device cannot detect the presence of other transmissions, it attempts to access the medium. Therefore, when directional communication beams are used, many client devices detect the medium as idle when in fact it is busy. This has an effect on the performance of the network and is referred to as the "hidden beam" problem.

In practice, a communication beam (e.g., directional beam) has a main beam whose width can be controlled by the size of the antenna aperture, and sidelobes which vary in different directions. However, these communication beams may have nulls in certain directions that affect the wireless network with a hidden beam. Since a given receiver's energy detect threshold is usually lower than it's decoding threshold, it is possible to direct a high power signal towards an intended client device and yet ensure a minimum transmit power towards other clients in the network so that the signal may be detected by other clients.

Complementary beam-forming ensures a minimum transmit power in all directions while preserving the shape of the main communication beam. The complementary beam-forming techniques also ensure that multiple transmit beams in arbitrary directions are complemented by another beam in all other directions. The complementary beam does not interfere with the intended beams and increases the probability that other users in the network can detect the signal.

The modified Butler matrix **1300** includes the antenna ports **400**(**0**, **1**, . . . , N−1, N) and a gain mechanism **1400** configured to modify the signal at output port **400**(**0**). A transmit signal is input to a corresponding input port of the Butler matrix and, in conjunction with the gain mechanism **1400**, a complementary beam is formed due to the increase in gain. The result is a directional communication beam from the antenna in a given direction. A complementary beam-forming, pre-combining implementation can also be implemented.

Mathematically, a complementary beam-forming, post-combining implementation may be described as:

$$y_i = \begin{cases} \gamma y_i & i = 0 \\ y_i & \gamma \geq 1 \end{cases} \quad 0 \leq i \leq N-1$$

where y_i is the power applied to antenna element i and γ is the gain value contained in the gain mechanism **1400**. To ensure the same output power as with no complementary beam-forming, the output voltage on all of the Butler matrix ports can be adjusted by a scaling factor:

$$G_s = \sqrt{\frac{N}{\gamma^2 + N - 1}}$$

The power for the main communication beam will then be:

$$\Delta P = \frac{(\gamma + N - 1)^2}{N(\gamma^2 + N - 1)}$$

or stated in terms of dB:

$$\Delta P_{dB} = 10 \log\left\{\frac{(\gamma + N - 1)^2}{N(\gamma^2 + N - 1)}\right\}$$

For example, for a sixteen element antenna array **302**, if γ=3.5, then the power loss is approximately 1 dB.

FIG. **15** illustrates a graph **1500** depicting the signal level output (dB) for certain ports of the modified Butler Matrix **1300** shown in FIG. **14**. Graph **1500** depicts the shape of a transmit communication beam **1502** without complementary beam-forming and a transmit communication beam **1504** with complementary beam-forming applied. In this example, the transmit communication beam is derived from a signal at port **400**(**0**) of Butler Matrix **1300**. As shown, the output with complementary beam-forming (e.g., transmit communication beam **1504**) has higher sidelobes in all directions and removes all of the deep nulls except for the nulls on the main communication beam. The peak power of the main communication beam is approximately one dB lower than that without complementary beam-forming.

FIG. **16** illustrates a transition diagram **1600** for a roaming client device that transitions from one communication location within a wireless network system to another. For example, client device **202** (FIG. **2**), while in wireless communication with access station **102** via directed communication beam **214**(**1**) may roam (e.g., move, relocate, transition, etc.) such that communication with access station **102** would be facilitated via directed communication beam **214**(**2**). A client device initially associates to one directed signal of the multi-beam directed signal system **206** by selecting the signal (e.g., communication beam) with the best signal at the time of association. However, because the client device may be portable and/or the wireless environment may change (e.g., due to device transitions, interference, etc.), the initially selected directed signal may not provide a continuous, or the best, communication channel over which to communicate information (e.g., in the data packets) and hence the client may have to roam and/or be associated with another directed communication beam.

Roaming is dependent on client device implementation, is initiated by a client device, and may not be directly controlled by the multi-beam directed signal system **206**. In most commercially available client devices, roaming is triggered when the channel quality (SNR) falls below a threshold. The channel quality assessment (SNR measurement) is based on received strength of a directed communication beam. To ensure that a client device is associated with the best signal, the multi-beam directed signal system **206** directs the client device to roam to the directed communication beam with the best signal quality using a beam-switching algorithm.

Additionally, to ensure seamless roaming between communication beams, the multi-beam directed signal system **206** implements Inter-Access Point Protocol (IAPP) which is defined by IEEE 802.11f to support interoperability, mobility, handover messaging between directed communication beams **214**, and coordination between access stations **102** in a wireless communications environment. Beam-switching can be implemented by the multi-beam controller **816** (FIG. **8**B) in the multi-beam directed signal system **206** to ensure that client devices are associated with the directed communication beam **214** having the best signal level and IAPP to ensure client-initiated seamless roaming.

The beam-switching algorithm disassociates a client device once it moves out of an associated main communication beam. However, such movement of a client device is difficult to detect in the wireless environment and disassociation may result in data packet loss and a long association procedure. The effect is particularly significant for client devices located between adjacent directed communication beams. Hence, the beam-switching algorithm will disassociate a client device when there is a determinable difference between signal qualities on different communication beams.

With reference to FIG. **16**, a client device may be described as being in a monitor state **1602**, a correct beam test state **1604**, and a force roam state **1606**. In the monitor state **1602**, a client device is associated with a directed communication beam **214** while the multi-beam directed signal system **206** (e.g., access station **102**) continues to sample and collect receive strength signal indications (RSSI) values for each data packet received from the client device. The multi-beam controller **816** recalculates a new measure identified as a smoothed RSSI value (SmoothedRSSIValue) over an RSSI window size (RSSIWindowSize) and compares it to an RSSI lower control limit threshold (RSSILowerControlLimit).

In the correct beam test state **1604**, the scanning receiver **822** measures the RSSIs and calculates a smoothed RSSI value (SmoothedRSSIValue) for the client device on each of the adjacent ports (e.g., communication beams). Samples of the RSSI window size (RSSIWindowSize) for the two adjacent ports are averaged and compared to the same parameter for the current communication beam to determine the best, or most effective, communication beam. In the force roam state **1606**, the client device is temporarily disassociated so that it cannot associate to the current directed communication beam.

An association transition **1608** to the correct beam test state **1604** occurs when a client device associates a directed communication beam **214**. From the correct beam test state **1604**, a correct beam transition **1610** indicates that a current communication beam is the best communication link between the client device and the multi-beam directed signal system. New RSSI values are sampled and a new lower control limit (LowerControlLimit) is recalculated. A scan timeout transition **1612** from the correct beam test state **1604** indicates that the scanning receiver **822** has been monitoring the adjacent communication beams for more than a roaming scan timeout duration (RoamingScanTimeout) without any decision about the correct beam.

From the monitor state **1602**, a sample RSSI transition **1614** indicates that the smoothed RSSI value (SmoothedRSSIValue) and the RSSI lower control limit (RSSILowerControlLimit) are re-calculated. A smoothed RSSI drop transition **1616** from the monitor state **1602** drops the smoothed RSSI value (SmoothedRSSIValue) to an RSSI lower control limit (RSSILowerControlLimit). A wrong beam transition **1618** from the correct beam test state **1604** indicates a better communication beam is identified that has an RSSI that exceeds the RSSI of the current communication beam by a signal drop threshold dB (SignalDropThreshold). The client device is disassociated from the current communication beam and a timeout transition **1620** occurs after a roaming time out (RoamingTimeOut). The state information corresponding to the client device is then removed (e.g., deleted, discarded, etc.).

The lower control limit parameter (LowerControlLimit) is calculated using both the mean and the standard deviation of RSSI as follows:

$$LowerControlLimit = \overline{RSSI} \sim 2\sigma$$

$$\overline{RSSI} = \frac{1}{N}\sum_{i=0}^{N-1} RSSI_i \quad N = RSSIWindow\ \text{Size in frames}$$

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=0}^{N-1} (RSSI_i - \overline{RSSI})^2}$$

The $RSSI_i$ is the RSSI value reported for frame i. The N−1th frame is the most recent frame. The smoothed RSSI value (SmoothedRSSIValue (S)) is calculated when RSSI values are sample when a data packet is received. The smoothed RSSI value is calculated as S_j=0.1*$RSSI_j$+0.9*S_{j-1}. This value is then compared to the lower control limit (LowerControlLimit) and if it is larger than the limit, the client device enters the correct beam test state **1604**. The IAPP seamless roaming enables seamless client-initiated roaming between communication beams within an antenna panel, between antenna panels, and between an antenna panel and third party access points (e.g., access stations, multi-beam directed signal system, etc.).

Methods for directed wireless communication may be described in the general context of computer-executable instructions. Generally, computer-executable instructions include routines, programs, objects, components, data structures, and the like that perform particular functions or implement particular abstract data types. Methods for directed wireless communication may also be practiced in distributed computing environments where functions are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, computer-executable instructions may be located in both local and remote computer storage media, including memory storage devices.

FIG. **17** illustrates a method **1700** for directed wireless communication. The order in which the method is described is not intended to be construed as a limitation, and any number of the described method blocks can be combined in any order to implement the method. Furthermore, the method can be implemented in any suitable hardware, software, firmware, or combination thereof.

At block **1702**, a directed wireless communication is generated for data communication with a client device. At block **1704**, the directed wireless communication is received at an antenna assembly, and at block **1706**, a directed communication beam is emanated for the data communication with the client device. For example, the multi-beam directed signal system **206** (shown in FIG. **2**) generates a directed wireless communication for data communication with client device **202**. Antenna assembly **208** receives the generated wireless communication and emanates a directed communication beam **214**(**1**) for the data communication with client device **202**. In an embodiment, the directed communication beam can be emanated from two or more antenna elements of the antenna assembly as an electromagnetic signal that includes transmission peaks and transmissions nulls within a coverage area of the directed communication beam **214**(**1**).

At block **1708**, the data communication is transmitted to the client device via the directed communication beam. At block **1710**, a second directed communication beam is emanated for data communication reception from a second client device, and at block **1712**, a second data communication is received from the second client device via the second directed communication beam. For example, an additional directed communication beam **214**(N) can be emanated from antenna assembly **208** for data communication reception from client device **204**. The data communication transmission (at block **1708**) can be controlled so as not to interfere with receiving the second data communication (at block **1712**) and optionally, transmitting the data communication and receiving the second directed data communication is simultaneous.

FIG. **18** illustrates a method **1800** for directed wireless communication. The order in which the method is described is not intended to be construed as a limitation, and any number of the described method blocks can be combined in any order to implement the method. Furthermore, the method can be implemented in any suitable hardware, software, firmware, or combination thereof.

At block **1802**, directed wireless communication is coordinated with client devices via directed communication beams emanated from an antenna assembly. For example, wireless communications are coordinated by the signal control and coordination logic **304** (shown in FIG. **3**) with client devices **202** and **204** (FIG. **2**) via directed communi-

cation beams **214**(**1**) and **214**(N), respectively, which are emanated from antenna assembly **208**. A directed communication beam can be emanated as an electromagnetic signal that includes transmission peaks and transmission nulls within a coverage area of the directed communication beam. Further, energy can be transmitted on a side lobe of a directed communication beam corresponding to a first client device such that a second client device will detect the side lobe energy and recognize that a data communication transmission is being emanated to the first client device via the directed communication beam.

The directed wireless communication can be coordinated such that only client device **202** receives a first directed wireless communication via communication beam **214**(**1**), and such that only client device **204** receives a second directed wireless communication via communication beam **214**(N). Coordinating directed wireless communication can include simultaneous data communication transmission to client device **202** via directed communication beam **214**(**1**) and a data communication reception from client device **204** via directed communication beam **214**(N). Further, the data communication transmission is coordinated so as not to interfere with the data communication reception.

At block **1804**, data communication transmissions are routed through a transmit beam-forming network to antenna elements of the antenna assembly such that a data communication transmission is communicated to a client device via a directed communication beam. At block **1806**, the directed communication beams are monitored for data communication receptions from the client devices. At block **1808**, data communication receptions are received through a receive beam-forming network from the antenna elements of the antenna assembly such that a data communication reception is received from a client device via a directed communication beam. For example, a data communication reception can be received from a client device with scanning receiver **822** (shown in FIG. **8**B).

At block **1810**, a determination is made as to which of multiple channels provides acceptable data communication transmission and/or reception with a client device. At block **1812**, information is maintained corresponding to one or more of the client devices. The information can include a transmit power level, a data transmit rate, an antenna direction, quality of service data, and timing data. Further, coordinating a directed wireless communication with a client device (as described in block **1802**) can be based on the information that is maintained (at block **1812**).

FIG. **19** illustrates a method **1900** for directed wireless communication. The order in which the method is described is not intended to be construed as a limitation, and any number of the described method blocks can be combined in any order to implement the method. Furthermore, the method can be implemented in any suitable hardware, software, firmware, or combination thereof.

At block **1902**, a client device is associated with a directed communication beam. For example, a portable client device **202** (shown in FIG. **2**) is associated with communication beam **214**(**1**) (shown in FIGS. **2** and **3**). At block **1904**, signal strength indications are received for data packets received from the client device via the directed communication beam. At block **1906**, a signal strength average for the client device is calculated from the received signal strength indications.

At block **1908**, adjacent signal strength indications are sampled for an adjacent directed communication beam. At block **1910**, a second signal strength average is calculated for the adjacent directed communication beam. For example, signal strength indications are sampled for an adjacent directed communication beam **214**(**2**) (shown in FIGS. **2** and **3**), and a signal strength average is calculated for the adjacent directed communication beam **214**(**2**).

At block **1912**, the signal strength average is compared to the second signal strength average and a determination is made as to which provides a more effective, or better, communication link. If the second signal strength average does not indicate that the adjacent directed communication beam would provide a better communication link than the directed communication beam (i.e., no from block **912**), then the client device association with the initial directed communication beam is maintained at block **914**.

If the second signal strength average indicates that the adjacent directed communication beam would provide a better communication link than the directed communication beam (i.e., no from block **912**), then the client device is disassociated with the directed communication beam at block **916**. At block **918**, the client device is re-associated with the adjacent directed communication beam. The method **1900** can then continue and be reiterated from block **1902**. Additionally, the method **1900** can be implemented for any number of client devices in wireless communication with a directed wireless communication system.

Although wireless communication system(s) have been described in language specific to structural features and/or methods, it is to be understood that the subject of the appended claims is not necessarily limited to the specific features or methods described. Rather, the specific features and methods are disclosed as exemplary implementations of wireless communication system(s).

What is claimed is:

1. A receiver for use in a wireless communications system, the receiver comprising:

an antenna, wherein the antenna comprises a first antenna element and a second antenna element;

a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna; and

a processor operatively coupled to the transceiver, the processor configured to:

receive a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously;

determine first signal information for the first signal transmission;

determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;

cause the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.

2. The receiver as recited in claim **1**, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.

3. The receiver as recited in claim **2**, wherein the first signal transmission and the second signal transmission are directional transmissions.

4. The receiver as recited in claim **1**, wherein the content comprises data configured to be used by the remote station

to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.

5. The receiver as recited in claim **4**, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.

6. A receiver for use in a wireless communications system, the receiver comprising:

an antenna;

a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna; and

a processor operatively coupled to the transceiver, the processor configured to:

receive a first signal transmission from a remote station via the antenna and a second signal transmission from the remote station via the antenna simultaneously;

determine first signal information for the first signal transmission;

determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver construct one or more beam-formed transmission signals;

cause the transceiver to generate a third signal comprising content based on the set of weighting values;

determine a plurality of signal strength indications for the first signal transmission;

determine a first signal strength average based on the plurality of signal strength indications for the first signal transmission;

determine a plurality of signal strength indications for the second signal transmission;

determine a second signal strength average based on the plurality of signal strength indications for the second signal transmission; and

cause the transceiver to generate a fourth signal based on the first signal strength average and the second signal strength average.

7. The receiver as recited in claim **6**, wherein the processor is further configured to: cause the transceiver to transmit the fourth signal to the remote station via the antenna.

8. A method in a wireless communications system, the method comprising:

receiving a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls;

determining first signal information for the first signal transmission;

determining second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals; and

transmitting to the remote station a third signal comprising content based on the set of weighting values.

9. The method as recited in claim **8**, further comprising:

transmitting the third signal to the remote station via the antenna.

10. The method as recited in claim **8**, wherein the first signal transmission and the second signal transmission are directional transmissions.

11. The method as recited in claim **8**, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.

12. The method as recited in claim **11**, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.

13. The method as recited in claim **12**, further comprising:

determining a plurality of signal strength indications for the first signal transmission;

determining a first signal strength average based on the plurality of signal strength indications for the first signal transmission;

determining a plurality of signal strength indications for the second signal transmission;

determining a second signal strength average based on the plurality of signal strength indications for the second signal transmission; and

generating a fourth signal based on the first signal strength average and the second signal strength average.

14. The method as recited in claim **13**, further comprising:

causing the transceiver to transmit the fourth signal to the remote station via the antenna.

15. An apparatus for use in a wireless communications system, the apparatus comprising:

an antenna;

a transceiver operatively coupled to the antenna; and

a processor operatively coupled to the transceiver, the processor configured to:

receive a first signal transmission from a remote station via the antenna,

the first signal transmission comprising first signal information, wherein the first signal information comprises one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data;

receive a second signal transmission from the remote station via the antenna, the second signal transmission comprising second signal information;

determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;

cause the transceiver to generate a third signal comprising content based on the set of weighting values.

16. The apparatus as recited in claim **15**, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.

17. The apparatus as recited in claim **16**, wherein the processor is configured to receive a fourth signal transmission from an interferer source, the fourth signal transmission being undesired, and the processor is configured to store identifying information concerning the undesired interferer source and the remote station.

18. The apparatus as recited in claim **17**, wherein the processor is configured to identify a further interferer signal transmission from the interferer source, and to identify a further desired signal transmission from the remote station, wherein the processor is further configured to prevent the transceiver from transmitting a fifth signal transmission via the antenna during reception of the further desired signal transmission but to allow the transceiver to transmit a sixth signal transmission via the antenna during reception of the further interferer signal transmission.

19. The apparatus as recited in claim **15**, wherein the set of weighting values are applied to the third signal, and wherein the transceiver is configured to receive a fourth signal transmitted from the remote station, and the processor is configured to apply the set of weighting values to the fourth signal.

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